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Education

A CONCEPT AND SYSTEM ARCHITECTURE FOR IT-BASED LIFELONG LEARNING

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Abstract—This article presents the vision 'A Concept and System Architecture for IT-Based Lifelong Learning'. The paper as a whole summarises the results of a project funded by the Ministry of Industrial Development of Sabah, Malaysia. The goal of the project was to develop a concept for IT-based Lifelong Learning including a case study based on a specific curriculum and considerations about potential business opportunities. Within the project experienced international researchers in the area of IT-based learning and training worked together in two preparation workshops and a final workshop about 'IT-Based Lifelong Learning Systems' in Sabah, Malaysia, in March, 1997. The paper is based on the experiences of the authors from the International Network of Institutes for Computer Graphics (INI-GraphicsNet‡) in several R&D projects and has been reviewed, refined and revised by a group of local experts as well as several well renowned international experts and local/regional experts (Appendix A). The editors of the vision paper are J. L. Encarnação, M. Mengel and P. R. Bono.

Section 1 presents first the motivation of the paper, then international trends and the vision of an IT-based learning infrastructure integrating all parts of the society. The resulting goal, advising on how to go forward into the direction of the named vision, finalizes the Introduction. Section 2 discusses the various roles of an IT-based learning environment and identifies user needs and requirements. Section 3 proposes concepts for, and an architecture of, a learning system for IT-based lifelong learning.

Section 4 focuses on the Technical Implementation of the proposed system architecture. A generic approach for IT-based lifelong learning based on a conceptual system architecture is presented. This approach distinguishes between the services and environment of such a system. Firstly, the services offered by the system are described in more detail. These services include data management, co-operation and security services that are role- and activity-independent and have to be adapted to the underlying technical resources. Then the environments, including authoring, delivery and administration environments realizing a specific functionality for a specific user role and activity, are presented. The section is completed by addressing issues for a concrete implementation including implementation guidelines and assessment criteria and an implementation strategy to reduce the technological risk is suggested.

Section 5 describes a case study which will be initiated cooperatively by leading experts from the fields of visualization, multimedia, interaction and communication. This case study provides a narrow vertical section through the layers of the approach to lifelong learning both to demonstrate its effectiveness and to permit the evaluation of its efficiency. Section 6 outlines a plan for the realization of the project as a whole. A glossary and bibliography complete the main part of the paper. In Appendix B (Recommendations), Appendix C (Project References), and Appendix D (Open Issues), are presented.

The experts from the International, Institutional, Network of Computer Graphics, designated by **, (Type I Experts) participated in and served as facilitators for the 'IT-Based Lifelong Learning Systems' Workshop in Sabah on March 11–13, 1997.

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1. INTRODUCTION

1.1. *Motivation*

The qualifications and skills of a country's population have always been one of its main bases for culture, prosperity, and influence. With the increasing complexity of our world, actual information and insight becomes more and more important for everybody. Today, education is based on teaching and learning in large classes, using paper, chalk, transparencies, some slides, a few videos, and nearly no animation and simulation. Books, articles, and conferences, including their proceedings, are used to exchange and distribute knowledge. Learning in groups is limited by the amount of personal tutoring support that is affordable. Today's means of learning and training no longer match the needs. Information technology is one of the major reasons for the complexity of our world but, in turn, potentially offers a means for its management. IT-based, lifelong learning is widely expected to be one of the most important techniques for keeping up with the steady advancement of our community.

1.1.1. *The need to increase learning efficiency.* In order to meet the requirements of our society, increasing numbers of students are populating the universities. Due to high personnel costs for both educators and students, education at universities has become a very expensive task for society.

Presently, students are confronted with stagnating numbers of educators. As a result, the guidance of the individual student is lower than before, which results in either a longer study time or a lower quality of their education. It is time to increase teaching and learning efficiency. To increase teaching efficiency, more effective teaching support for the lecturers is needed (especially liberation from all non-creative sub-tasks that can be automated). Increasing learning efficiency means better learning tools (especially individualized responses to immediate students needs; see also Refs [1, 2]).

By providing better support for lecturers (particularly a means for easy exchange of lecturing expertise), by using better media for knowledge transfer (like on-line access to external applications and simulators), by profiling learners in order to serve them individually, and by providing a wide spectrum of learning scenarios including group work, the quality of studies can be increased and their length shortened. At the same time, the creativity of lecturers, actually handicapped by repetitive basic managing tasks, can be set free.

1.1.2. *Competitiveness through learning and training.* In order to stay competitive in a quickly evolving market, everyone in industry, academia, government, and commerce needs to enhance and update his or her skills and qualifications. Unfortunately, a large percentage of these people cannot practice lifelong learning at all. Many reasons constrain people who would like to enhance their knowledge. In most cases, training implies leaving work for a substantial amount of time and paying substantial fees for courses that cover only a small percentage of their individual needs. This is especially valid for small or struggling companies. They cannot train their employees as large, wealthy companies can. As a result, the rich get richer, while the poor get poorer. To overcome this situation, flexible, customizable, continuous, and individual training-on-demand is requested—training that must be independent of both time and place (so-called, 'just-in-time training' or 'on-the-job training') and must provide high quality training at reasonable prices.

It is evident that jobs go where the skills are and skills stay where the jobs are. Education and training institutions are typically found in regions with high population density, and so are skilled people and jobs. Although industry is tending to migrate to more rural areas, education and training do not necessarily follow, thus reducing the ability to attract these jobs. IT-based services for learning and training (also enabling integration of internal company training) will make these jobs more attractive. Larger companies with plants all over the world can clearly profit from IT-based training facilities, since they allow the exchange of company-specific expertise rapidly and easily.

1.1.3. *Integration of society through learning and training.* Information and service access through IT technology becomes increasingly useful, attractive, and important for everyone. The availability of affordable, high-performance equipment and software, offering effective and comprehensible interfaces for non-experts, is steadily lowering the gap between average people and high technology. This applies to everybody—equally to children at school and elderly people, to the well-educated or the poorly-trained parts of the population, to people at home and at work, and to the unemployed or under-employed, including especially those with physical limitations.

Learning and training with IT-based services will clearly make use of the elements of 'edutainment' and group activities. They have the potential to constitute an effective integrating factor in our society.

1.1.4. *Learning and training as a market.* Harmonic integration of IT-based services into our society will open important new markets. One of these will be the education market (see, e.g., Ref. [3]), as is already seen by corresponding activities. These steps go hand in hand with the trend of merging the whole world together into one global, network-linked village. In this global village, services like tele-working, tele-conferencing, tele-shopping, tele-teaching, and the global information market are key technologies. These technologies need to be available in time, in order to stay competitive in this upcoming new and open market. This does not

only concern institutions that provide educational services, such as universities and schools, but also industry and the general public.

1.2. *International trends*

Basic as well as applied research in the field of computer-based training has been conducted all over the world for several years. The first steps in the European Commission were done in the mid 1980's, when it started a systematic program on technologies for education and training. The pilot projects led to the Exploratory Action on 'Developing European Learning through Technology Advances' (DELTA). They are continued in the area of 'Telematics and Distance Learning', with projects running from 1992 to 1995. The final report [4] describes the results of the 30 DELTA projects, which were supported with more than 60 million ECU from the European Commission.

The *Industry Research Task Force on Educational Software and Multimedia* observed the whole field of 'Educational Multimedia' in Europe and summarized the results in a working report [5]. This study determines the current situation and future prospects in education by formulating various statements. Those statements of general interest, even outside Europe, are stated below.

Statement: The emergence of educational multimedia at home

Stimulated by the steady reduction of multimedia equipment prices, the mass market for educational multimedia, consisting of products recorded on optical disks and services that can be accessed by the telematics networks, cannot fail to grow rapidly in the mid 1990's. The availability of broad-bandwidth networks at affordable prices towards the end of the century will promote the growth of new, top-end, educational multimedia services, provided that European industry ensures the availability of user-friendly and affordable telematics applications to individual learners in the home environment.

Statement: Primary and secondary education—great potential

Numerous experiments have shown the educational value of multimedia. However, there are several obstacles to the widespread use of educational multimedia in schools:

- the lack of user-friendly multimedia equipment and software for teachers and students,
- insufficient quality and quantity of equipment, which is often technically obsolete, sometimes insufficiently used, and rarely connected to telecommunications networks,
- insufficient quantity and quality of educational software adapted to the needs of users,
- the difficulty of integrating educational multimedia into the educational experience of teachers,
- the lack of teacher training and information.

Statement: Universities—a laboratory for new forms of education

As a general rule, universities internally produce multimedia educational products for high-level training on a non-commercial basis. They are increasingly turning towards the use of broadband telecommunications networks for the distribution of courses and for joint research. However, in the mid 1990's, the costs of equipment and multimedia services and the associated high telecommunications tariffs still impede the spread of educational multimedia in universities.

Statement: Multimedia—facilitating innovation in teaching methods

Multimedia has demonstrated its pedagogic efficacy in numerous pilot experiments. Its use in day-to-day teaching practice can only be achieved if innovative teaching processes receive a better reception both by educational institutions and by society at large. Only then multimedia will find its place in the context of the evolution of the educational system.

The Task Force on Educational Software and Multimedia produced a state-of-the-art report on educational multimedia in different contexts of use. This report covers, besides the European Union, also main non-European countries, such as Australia, Canada, Japan, Russia, and the United States of America. This report is appended to the above named working report [5].

The following examples of on-line providers, universities, and corporate training providers represent just a small sample of the number of offerings in multimedia education:

- The Massachusetts Institute for Technology [6]
- The Gartner Group [7]
- The Open University [8]
- The London Guildhall University [9]
- EUROPLACE, a trans-European network of universities [10]
- Reykjavik Institute of Education—Iceland [11]
- The University of Phoenix-Online Campus [12]
- The Christopher Newport University [13]
- The Metro State College [14]
- The Athena University [15]
- The University of Hong Kong [16]
- The Fernuniversität Hagen [17].

In its report 'Realizing the Information Future' [18], the National Science Foundation (NSF) of the United States also addressed the issue of network-supported education and training. Moreover, it also tackled the conjunction of IT-based learning with digital libraries. Digital Libraries will play an im-

portant role in lifelong learning in the future. They complement research and education and can be regarded as access points for both users and providers of information via networks (for concrete activities in the field of digital libraries, see, e.g., Refs [19, 20]).

1.3. *Vision and goal*

1.3.1. *The vision.* Our global vision is the integration of a learning infrastructure in all parts of society. This new learning infrastructure will not replace but enhance the already existing learning institutions. We assume, because of the wide range of what needs to be integrated, that content, formats, and attitude towards subjects will vary to a high degree. Due to the varying and information-specific needs for protection, access rights to learning materials have to support several security levels. The knowledge represented in computer-based learning material should be represented in a homogenous way, in order to enable a transparent domain, which can be seen as a common information universe, or 'infoverse', as shown in Fig. 1.

Figure 1 shows the idea of a common infoverse, in which the technical and administrative framework in the middle carries knowledge in formats of computer-based learning material. The framework interconnects all areas of society, which both provide and use materials. Considering the wide availability of adequate equipment, connectivity, and infrastructure, we foresee that a market for training services, learning, and training will arise throughout the world.

1.3.2. *The goal.* Setting up a framework for IT-based learning and training that provides the potential for the scenario stated above means inventing an approach. The realization of this vision will be the result of several years or even decades of development rather than an instantaneous process. Many of the main features (such as multiple-use and re-use of course material) will not become really effective until the framework, including a certain amount of courseware, is in place.

The specific goal within the broad scenario is to support lifelong learning by people from 18 to 80 years of age centered on the scientific and technological disciplines. Courseware development will clearly be the main cost factor, surpassing the expenditure for system software, equipment, and communications by an order of magnitude. Therefore, the innovative learning and training environment is best located in an academic environment with its inherent focus on learning and training, its subject matter and pedagogic qualifications, its competence in systems and software, and its long-term societal view with respect to return on investment.

Following successful implementation in the university area, the learning and training environment can be extended to industrial usage. This, again, will cultivate the ground to make the environment open to society in general. As a consequence, a large market for learning and training services will be opened up. Within the Malaysian environment, the following steps are required to implement this process:

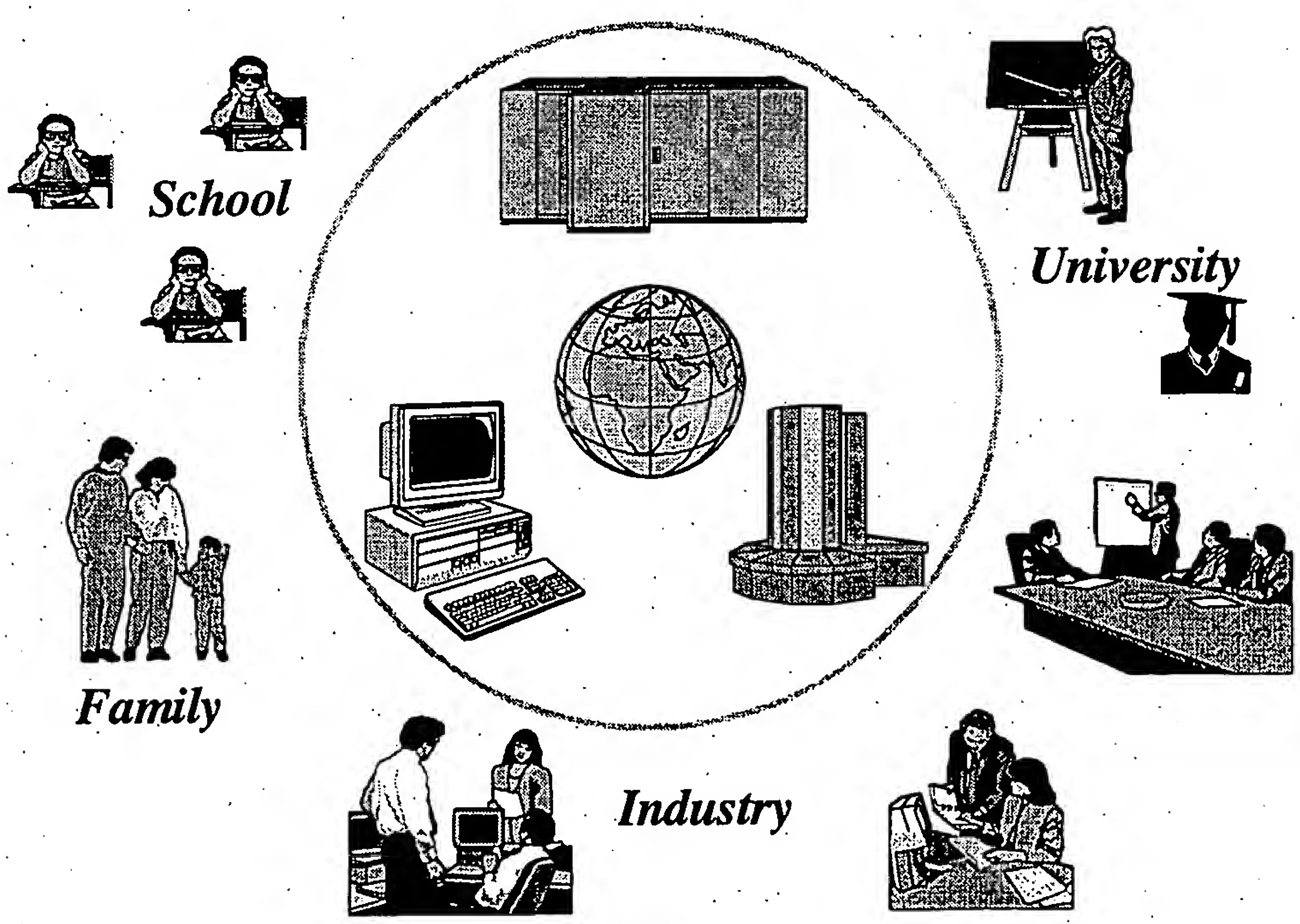

Fig. 1. idea of a common infoverse.

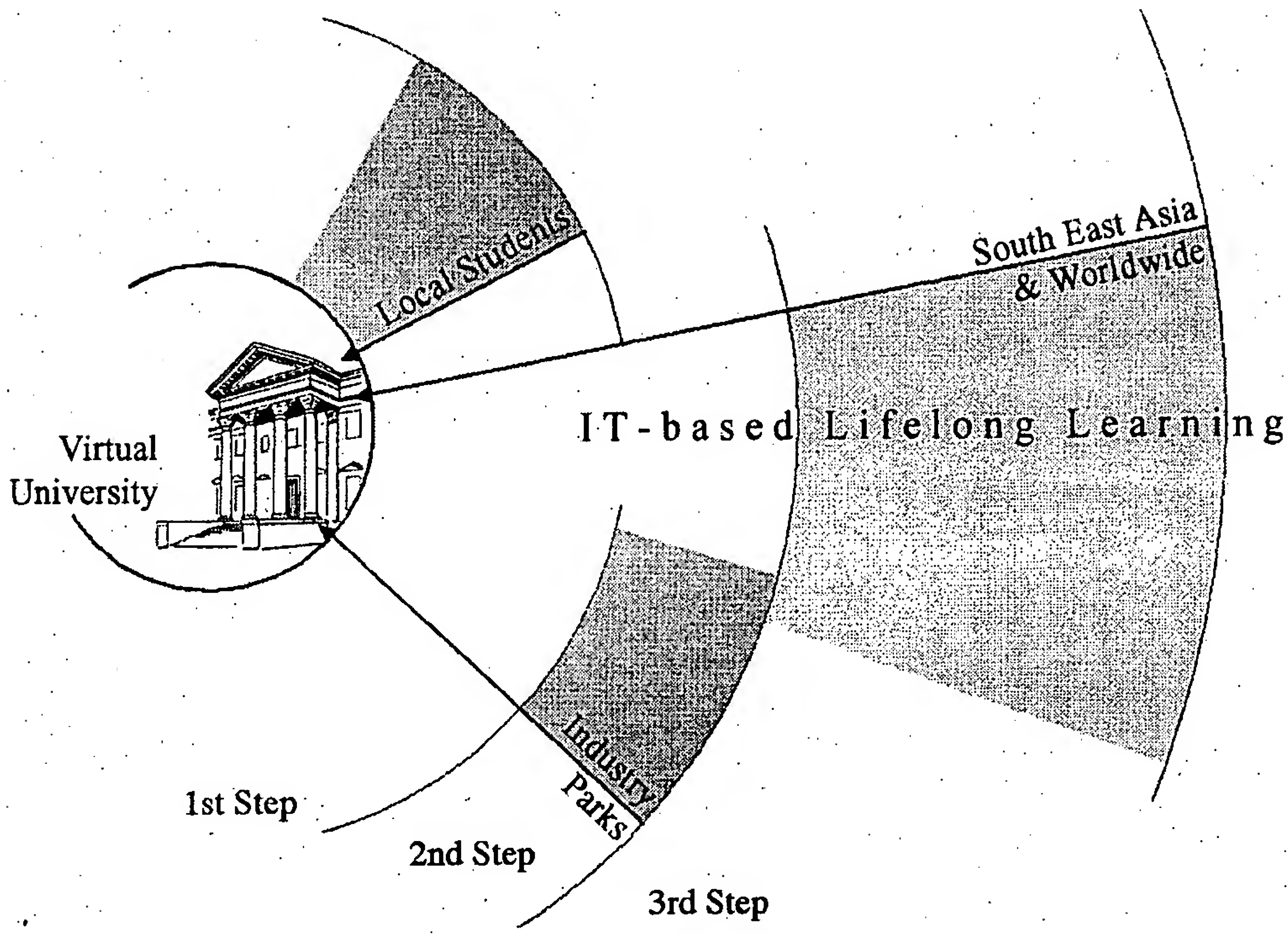

Fig. 2. Establishing IT-based Lifelong Learning.

1. Integrating an IT-Based Learning System into an Institute of Higher Education.
2. Providing IT-based training and learning to industrial parks.
3. Exporting training and learning, first to the South–east Asia region, and, later, to the whole world.

This evolutionary process is also shown in Fig. 2.

This vision paper focuses on concepts and realization issues for an environment that enables this stepwise implementation of IT-based Lifelong Learning. The goal of this stepwise implementation is to support lifelong IT-Based Teaching and Training (ITBT) by people 18 to 80 years of age, mainly centered on scientific and technological disciplines.

1.4. *Structure of this document*

The structure of this document is as follows: Section 2 discusses the various roles of an IT-based learning environment and identifies user needs and requirements. Section 3 proposes concepts for and an architecture of a learning system for IT-based lifelong learning. Section 4 focuses on the technical realization of the proposed system architecture. These sections present a generic approach to IT-based lifelong learning, which covers successive layers of courseware, personnel, administration, IT-learning technologies, and network infrastructure. Section 5 describes a case study, which will be initiated cooperatively by leading experts from the fields of visualization, multimedia, interaction and communication. This case study provides a narrow vertical slice through the layers of the approach to lifelong learning both to demonstrate their effectiveness and to permit the evaluation of their efficiency. Section 6 of this Concept and Architecture Paper will then outline a plan for the realization of the complete project. A glossary, bibliography, and a list of tables and figures complete the paper.

This paper does not address pedagogic issues related to delivering IT-based life long learning, nor does it address issues relating to how the delivery system can adapt to local cultural conditions (e.g., different languages, accepted cultural metaphors). Equally, this paper does not address the implicit teaching of social values through the technology proposed, nor didactic mechanisms for explicitly instilling cultural or social values through IT-based lifelong learning.

2. USER NEEDS AND REQUIREMENTS

2.1. *Summary*

This section concentrates on user needs and requirements for an IT-based training system. Before the concrete requirements are described, the following various roles and instances in preparing and delivering educational materials are described:

Author
Learner or trainee
Teacher
Tutor
Administrator.

Based on this classification, the user needs and requirements of the different roles are described in detail for each of them.

In the rest of this Concept Paper, we introduce the phrase, 'IT-Based Teaching and Training', known by the acronym, ITBT. The term ITBT is modeled after Computer-Based Training (CBT), but it will be used in a broader, more modern, more comprehensive sense. That is, ITBT encompasses IT-based delivery and support for all the learning scenarios described herein, while CBT will continue to refer to what is already commercially available as training technology today, whereby 'computer-based' is the main focus. ITBT also considers and integrates functionalities related to the Internet, intranets, and the World Wide Web.

2.2. *Roles involved*

There are several different roles in the process of computer-based training, such as those of courseware *author* and *learners* or *trainees*. In a network-based learning environment, however, additional roles, which are not needed in an individual, on-line learning scenario, can be identified, such as those of *tutor*, *teacher* and *administrator*. The relationships between these roles are illustrated in Fig. 3. The figure shows the involvement of all roles mentioned above. The gray box in the middle of the image represents the Learning and Training Center (LTC), where all training material is available and accessible. Furthermore, user accounts and user-specific data are located there.

Authors create their courseware either by themselves or in collaboration and deliver it to the LTC. The trainees access the learning material either by directly connecting to the LTC or by getting taught by a teacher. In addition, learners might communicate directly with each other, if group learning is offered. If needed, a human tutor supplements the learning process by advising the learners, both individuals and learning groups.

The LTC is maintained by one or more administrators, who organize and manage the user accounts, the accounting and billing, as well as the check-in of new courseware and its quality control. As shown in Fig. 3, a LTC might be connected to other LTCs. This networking is an additional issue for administration.

The following sections present user needs and requirements of the various roles: 'author', 'learner', 'teacher', 'tutor', and 'administrator'.

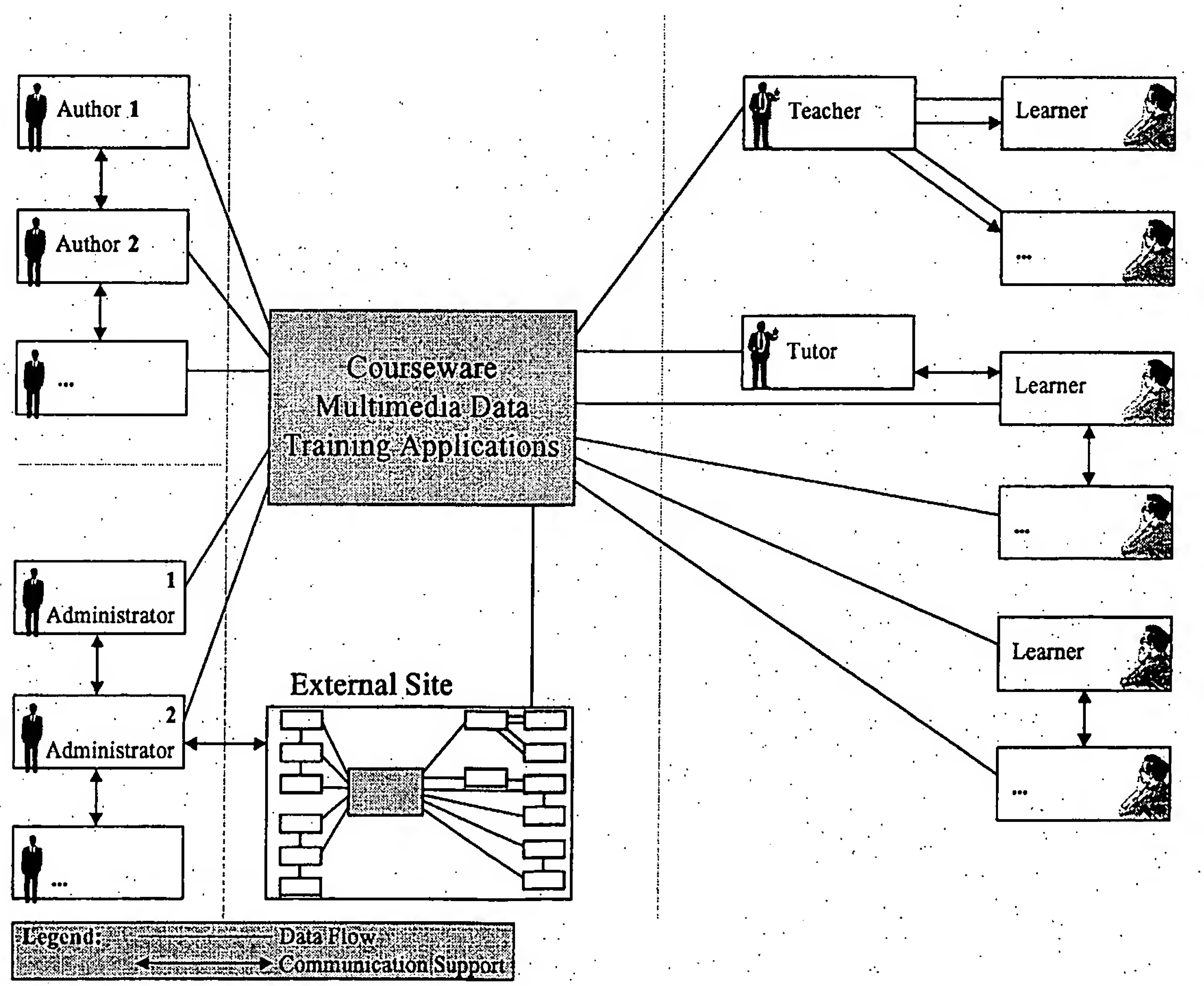

Fig. 3. Roles in an IT-based Learning Scenario.

2.3. *Author requirements*

2.3.1. *Description of author roles.* While user needs and requirement analyses for many systems are usually determined from the learner's viewpoint, requirements and needs of the authors are often not represented sufficiently. As a result, many ITBT systems can be used only by programmers, who frequently lack the pedagogic, ergonomic, and, in many cases, the content-related knowledge necessary to create a ITBT course as well. The result is summarized in Ref. [18]: "A substantial number of interactive CBT programs in the market are didactically unsatisfactory drill instruments that teach only facts. It is hoped that, in the area of Computer-Based Training, standards for the user interface ergonomics, for screen layout, and for didactic structuring as part of a standardized system architecture are being established. At present, the first signs of this are not even being seen".

This dilemma can be overcome starting with a clarification of which different tasks have to be performed in a ITBT project, which skills are required for them, and which personnel are appropriately qualified for it.

As described in several publications (e.g., Refs [21, 22]) describing the multimedia authoring of a commercial, high-quality ITBT project, the following categories of people should be collaborating:

Content expert(s)
Didactic and pedagogic expert(s)
Designer(s)
Programmer(s)
Media expert(s).

Furthermore, the provision of a courseware curriculum in an open environment requires personnel for managing the course material, for quality assurance, and for marketing the courseware.

A typical situation showing cooperation among the different groups while implementing the ITBT course is given in Fig. 4 which shows that most authors' expertise is passed indirectly into the ITBT course. The programmer is the only one directly coding the courseware. This can be identified as one of the main reasons for the existence of so many bad CBT courses. The following scenario (see Fig. 5) should be achieved to allow direct input from the different expert authors into the ITBT course.

In this scenario, the different author groups have different user interfaces, which are optimized for their specific authoring tasks. The different tasks are listed in Table 1.

2.3.2. *Required authoring scenarios.* For the authoring process, two scenarios can be distinguished, individual scenario and the cooperative authoring scenario.

In the individual authoring scenario, one person plays basically the different roles described above. However, this individual work paradigm might be enhanced by external services, e.g., for time consuming media production.

In the cooperative authoring scenario, different people might be playing the *different* authoring roles. Furthermore, it might be possible to have

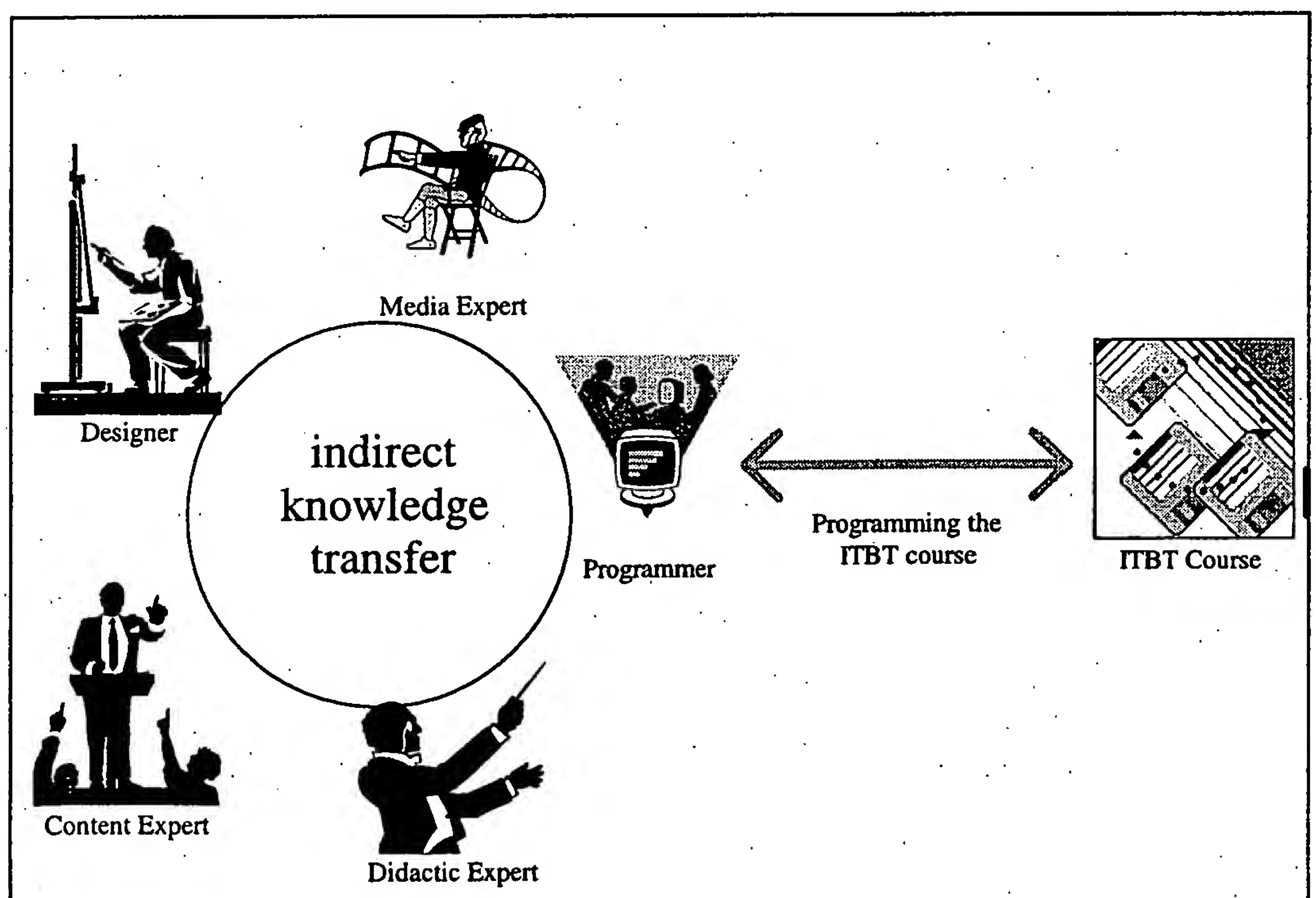

Fig. 4. Typical ITBT Authoring situation today.

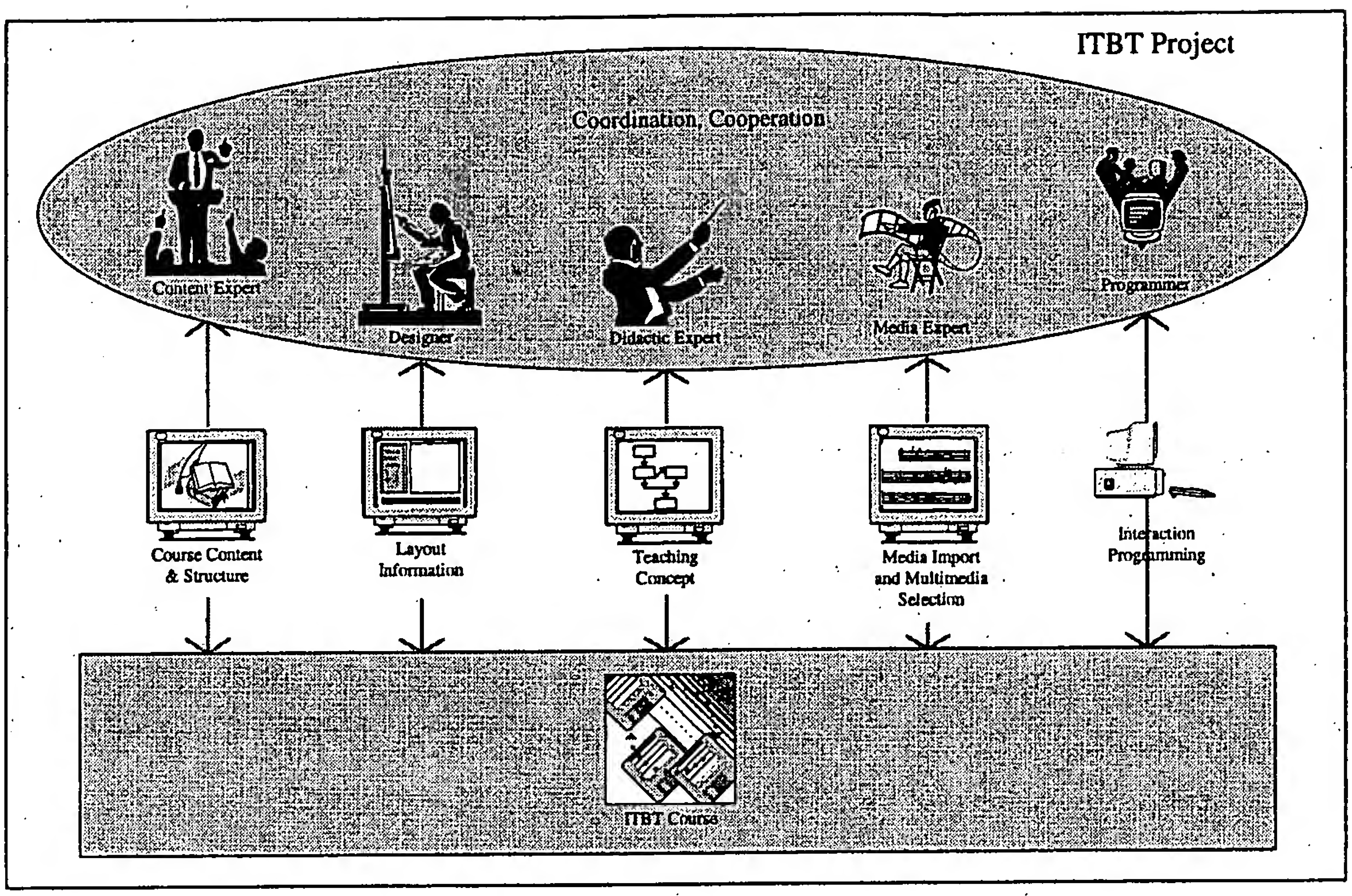

Fig. 5. Individual Authoring Interfaces for different experts.

different people playing the *same* role, e.g., two universities working together on one joint curriculum.

2.3.3. *Functional author requirements.* Based on the author roles mentioned above, the corresponding tasks and the distinct authoring scenarios, different requirements for the various identified roles can be derived. The following is a summary of the functional author requirements:

- workflow support of the authoring production process
- individually adaptable, easy-to-use authoring interface
- easy maintenance (modification and update) of the courseware
- mechanisms to ensure the Intellectual Property Rights related to the course material, which is created by the authors (security, copyright...)

Table 1. Authoring roles and their corresponding tasks

Authoring Roles	Task
Content Expert	Topical specification and detailed description and breakdown of the subjects. This task is closely related to the traditional breakdown of a book, in which the content author divides the content into paragraphs, subchapters, and chapters.
Didactic Expert	Defining the course structure and the course flow sequence. This task is similar to structuring a lecture, in which the teacher may first present an example for motivation, then a theoretical presentation, followed by a practical exercise, and then a test in order to determine whether the content was understood.
Design and Layout Expert	Defining the user interface and the interaction techniques. Concerning passive media, the process is related to the traditional task of laying out a brochure: • a background and the corresponding foreground colors are defined. • the title area, text areas, and graphical areas are defined. • the text sizes and styles are defined. • Concerning interactive media, the task includes: selecting an appropriate metaphor design and layout of interaction elements design of the behavior of interactive objects, etc.
Media Expert	Professional production and format adaptation of multimedia material of all kinds (mainly video clips and sound tracks). This task is very closely related to material production for movies. The media experts produce small shots, which a cutter then arranges into bigger parts and, finally, into the complete movie.
Programmer	Interaction programming; programming of embedded simulations, animations, and microworlds. This task is similar to programming stand-alone simulations. Some further requirements are anticipated, such as different levels of enabling/disabling the freedom implicit in user-controlled parameters of the simulation.

- sharing of courseware among different authors
- support of multiple use and re-use of courseware
- retrieval of existing courseware.

In particular, the last three requirements are highly important, as they are needed to achieve a decrease in the average production time and cost of each delivery. Multiple use of courseware should also increase the return on investment for expensive, high-quality course material.

2.4. *Learner requirements*

2.4.1. *Description of the learner role.* The classification of the term 'learner', can be based on profession (e.g., student or industrial trainee), location, and learning paradigm used. The different learner types considered within this document are illustrated in Fig. 2 and they can be separated into students at institutes of higher education, trainees from enterprises, and private individuals, who are interested in learning during their leisure time.

Students usually learn either on the university campus or at home. On campus, learning can take place within several different learning paradigms, of which the following are foreseen to be the most prominent: (1) the multimedia-enhanced traditional lecture, where a professor holds a lecture at a specific time and location, using an IT-based system as support, (2) the distributed lecture where, at a fixed time, a lecture is distributed with IT technology to different lecturing locations, and (3) individual learning at IT-based learning places on campus. The individual learning places can be specialized for the respective learning tasks, such as time-shifted lecture participation in special work-labs with high performance audio and video connectivity, but they can also be organized as pools of learning places, with normal state-of-the-art multimedia PCs. At home, students typically learn individually. However, if they have adequate hardware and networking equipment, they can also build learning groups or can use time-shifted lectures.

In contrast to the student situation, we anticipate three different learning locations for industrial trainees, namely learning centers, the place of work, and the home. In learning centers, trainees will learn in group seminars, which cover everything from multimedia-enhanced lecturing to group work in high performance laboratories. At their place of work, trainees can use IT-based learning for two main learning goals. The first goal is the satisfaction of acute learning needs, the so-called learning-on-demand. The second goal is continuing professional education. Because places of work do not necessarily have to be limited to one location (e.g., for the traveling salesman), mobile places of work have to be taken into account.

The third learning group covers people 'interested in learning' in general, including the unemployed and the underemployed. The two main learning locations of these people will be in their homes and at special seminars, e.g., organized as adult education, such as evening classes. These students will often not be enrolled in a degree-granting program.

2.4.2. *Required learning scenarios.* The three categories of learners mentioned above and the corresponding locations can be grouped into the following different abstract learning scenarios:

the individual learning scenario (one learner working at his/her learning place)

the group learning scenario (several learners collaborating at connected learning places)

the lecturing scenario (one lecturing place with several, synchronized learners).

Particularly in the individual and group learning scenarios, additional enhancements can be achieved with the support of an online tutor (see below). The tutorial support has to cover the area of helping with technical problems and related administrative tasks, like registration for courses or examinations, and also learning-content-specific tutoring. Therefore, one more learning scenario is needed which is, however, orthogonal to the above scenarios:

the tutoring scenario (one tutor at his/her tutoring place advising one learner or a group of learners).

These learning scenarios are also discussed in some detail in Section 3.

2.4.3. *Functional learning requirements.* The analysis of the functional requirements of learners allows a differentiation between general learning-inherent needs and specific needs of IT-based learning. The general learning-inherent needs are high efficiency and interesting topics, good quality, an easily useable and didactically proven concept, and the possibility of certification. Beside these general needs, the following functional learning requirements for an IT-based learning system are foreseen:

- independence of time and place
- access to demand-specific courseware
- adaptation to individual needs
- effective discussion in groups (person to person support)
- effective distributed courseware presentation adapted to group needs (synchronization between group members, role-playing games, control-passing)
- easy integration into a traditional lecture scenario
- support of synchronous and asynchronous lecture distribution
- effective help built into the system for administrative and technical questions
- effective tutor support for content-related questions built into the courseware.

2.5. *Teacher requirements*

2.5.1. *Description of the teacher role.* The role of the teacher is derived from the teaching scenarios at institutes of education (mainly university). The term 'lecturer' at universities, which is nearly synonymous with 'teacher', reflects the fact that, in the past, a large percentage of the visible part of teaching was done by lecturing.

Teachers are not inherently the originators of all the knowledge they teach from their lecture notes. Frequently, teachers assimilate, re-arrange, enrich, and model knowledge already available from diverse sources (e.g., from books, papers and conference proceedings). These preparations for knowledge transfer clearly take about 80% of the work dedicated to teaching. In Europe, teachers are usually accustomed to the delegation of work through advising and being assisted by one or two researchers (to assist with the organization of exercises and tests), by a secretary (to help with the production of lecture notes and transparencies), and by some students (to provide tutoring support for the students taking the class).

The role of the teacher with respect to his or her goals remains the same as in traditional teaching. He or she is the mediator between the material or knowledge to be taught and the learners, and, furthermore, he or she will be responsible for the success of the learning process. The means for the preparation of knowledge transfer are, however, changing now while the support for knowledge transfer itself will advance.

2.5.2. *Required teaching scenarios.* Concerning the preparation for knowledge transfer and compared with traditional procedures, the main advantage will be the fact that it becomes possible to advise the learner by coding pedagogical rules into the courseware. Another very important effect is the fact that teachers can now easily exchange pedagogical and didactic expertise by exchanging courseware. This leads to a much higher multiplication factor applied to the efforts of the teachers.

Teachers will furthermore profit from much more substantial and rapid feedback concerning the learning success of their learners and will be able to react appropriately. On the other hand, a remarkable percentage of the workload will be taken from them in those areas where a computer can take their part; these are especially the standard tasks of the teachers—tasks that do not require their full range of expertise, like presenting fact-oriented knowledge or like prescribing exercises.

Summarizing the above effects, teachers will do more work in their high-level areas of expertise by doing authoring work and by identifying, selecting and adapting excellent courseware modules produced by other experts. They will spend more time in quality enhancement of their courses dependent on the success rates of their learners. On the other hand, their personal presence in teaching activities will be lowered while their influence range, measured by the number of students taught, will grow in the areas of their centers of expertise.

Concerning knowledge transfer itself, one can distinguish between two scenarios: *computer-supported traditional lecturing* and *guided individual learning* in electronic classrooms.

In the first case, the teacher presents the course material to a group of learners, e.g., by means of an electronic black board. This teaching paradigm is very similar to traditional teaching except for the usage of fully digital presentation including its advantages like integration of animation and simulation. Nevertheless this teaching paradigm allows, of course, no direct interaction and exploration by the students.

The electronic classroom, however, is a much more advanced scenario. Here, each learner or small group of learners (2–3) works in front of a computer in order to interact with the content to be learned and/or explored. The teacher supervises the learners and can influence online the course operation based on the learning success of the learners. Feedback for this evaluation can be given by direct 'human–human communication', by course-inherent exercises or by questions raised from the learners either publicly or anonymously via the learning system.

For both teaching scenarios it can be considered that learners can access the 'lessons' from a remote site as well. Here face to face contact from teacher to learners, which is especially in the traditional lecturing scenario of great importance, is possibly replaced by video contact. It is expected, however, that the role of the teacher in individual learning scenarios will converge towards our current understanding of tutoring.

2.5.3. *Functional teacher requirements.* Based on the described tasks of the teachers in the different scenarios, the following functional requirements can be derived:

powerful search engine specialized for courseware,

detailed and statistical feedback from the learners,

authoring interface tools and development environment, scaleable to the technical expertise of the teachers, to allow the creation of lecture presentations on demand,

dedicated interactive courseware for lecturing support,

broadcast capability of a presentation session including group dialogue tools,

an interface for the observation of learners and online manipulation of courses,

synchronous and asynchronous communication capabilities up to audio and video conferencing and session-sharing in groups,

tools for exercising and certification of courses.

2.6. *Tutor requirements*

2.6.1. *Description of the tutor role.* Tutors assist teachers or their assisting staff conforming to their own expertise. Traditionally they participated in the preparations of lectures, exercises and tests by performing mainly routine tasks. In the tasks of knowledge transfer, they took the place of 'personal multipliers' for the teachers and their assistants. This will also go on in the future, and the tutor-tasks will change with the changing tasks of the teachers and their assistants. In both individual and group learning scenarios, the access to tutoring support will go on to play a significant role.

Independent from the access method to the tutor, online or off-line, the goal was and will remain to give the learner the feeling of getting individual, qualified, and responsive support easily. There are various ways in which a tutor can support the learner(s).

The tutor could serve as a help desk, could guide the learner through problems toward the desired goals, and show the learners the critical situations. In group learning scenarios, his or her task is even larger. It includes, among others, the chairing of group sessions as well as initiating and controlling role games. In any case access to the learners' profiles and the ability to monitor the learners' successes should support the tutoring process.

The subjects on which a tutor might be consulted include both technical and administrative questions and, more importantly, the learning of content-specific issues.

A further important task of the tutor is to be the communication channel between the learners and the course authors. He or she is the first person to get feedback about the course quality and level of difficulty.

2.6.2. *Required tutor scenarios.* From the technical point of view, we can distinguish two scenarios: off-line and online tutoring.

In the off-line tutoring scenario, the learner can submit questions or raise problems—for example, via email. Within a defined time the tutor answers the question and sends it back to the learner. In parallel with this, the tutor could edit a list of frequently-asked questions, which are directly accessible by the learners.

The alternative scenario is to access the tutor online. Here we see several levels of communication, which depend strongly on the infrastructure and technology available:

Chat
Audio
Video
Application Sharing.

Of course, full audio and video communication together with application sharing will enable the best tutoring quality. However, due to the restrictions given by the infrastructure, an incremental process can be foreseen.

2.6.3. *Functional tutor requirements.* Based on the tasks described for the tutors in the different scenarios, it can be seen that the requirements placed on tutors and teachers are almost identical. In contrast to teachers, for tutors only individual tutoring has to be supported as listed in the following:

- synchronous and asynchronous communication capabilities,
- audio and video conferencing,
- methods and tools for Computer Supported Cooperative Work (CSCW),
- token passing techniques,
- applying the learners' workplace to the tutors' systems and vice versa,
- tools for monitoring the users' learning success,
- access to courseware modules of the learner,
- access to courseware modules that provide answer-book functionality.

2.7. *Administration requirements*

Typically, for universities, a clear administration structure is established, covering all aspects of traditional lecturing and higher education. Traditional courses and examinations require approval and certification at a university or national level, for which bodies currently exist. Initially, these bodies would need to evaluate, approve, and certify the ITBT courses, too, through the mechanisms outlined in Section 3.5.6. Use of an IT-Based Learning System leads to additional requirements. The following subsections, therefore, focus only on these additional requirements and needs.

2.7.1. *Description of administration roles.* The administration of an IT-based learning system, as shown in Fig. 3, has to handle the following tasks:

- administration of the community of producers, service providers, users and managers,
- administration of the technological and networking infrastructure,
- maintenance of the system,
- cross-server site administration for cooperating Learning and Training Centers,
- administration of the embedded local and external courseware, including release control,
- counting the accesses to courseware and learning services.

In the case where several interconnected LTCs are being considered, the administration might be divided into two hierarchical levels:

The top level of administration is responsible for the cross-LTC issues (such as quality control, and cross server accounting schemes) and coordinates the local administrator.

The second level of administration is that of the local LTCs. It covers especially issues like courseware organization and supervision, local system maintenance, and management of user-data.

2.7.2. *Functional administration requirements.* Based on the administrative tasks determined above, the following functional administration requirements for an IT-Based Lifelong Learning System can be derived:

an easy 'plug and play'—like installation support,
easy administration of the courseware,
easy administration of the different user groups,
monitoring tools for user activities,
integrating accounting and billing support,
ensuring secure access (to user data and courseware); different access levels and different corresponding user groups must be maintained,
ensuring Intellectual Property Rights and copyright constraints,
uniform administration and control of different learning scenarios and delivery scenarios,
supporting the courseware exchange among different server sites.

3. CONCEPT FOR THE SYSTEM ARCHITECTURE

3.1. *Summary*

The main motivations for the creation of an IT-based system enabling the use of IT-based Lifelong Learning were explained in Section 2. This section presents all the system architecture and the relationships between its different components in further detail.

Within this new philosophy, there is a need to think about the new roles that each participant will have. There will be modifications in the way a learner receives information (new learning scenarios will appear) and in the information itself. Because new technologies allow overcoming traditional distance and space constraints, it is necessary to take advantage of this fact; namely, the possibility of integrating different knowledge from experts scattered around the world.

Taking into consideration that all the actors involved will have different roles, the administrative role will also be different from the traditional ones. There is a need to supervise the whole process, ensuring its quality and its correct operation.

3.2. *Learning scenarios*

Computer-based learning and training has to overcome the restrictions of traditional learning and teaching. It has to fulfill various user requirements, such as providing up-to-date and high-quality learning material, a didactically effective and motivating presentation of knowledge, as well as an easy-to-use and flexible environment. Besides these general requirements for quality, efficiency, and effectiveness of learning are additional key requirements for a successful and widely-accepted ITBT system.

Considering the users' acceptance, there has to be a clear understanding of the user community for ITBT systems, which can be differentiated into three groups (see Section 2.3.1):

industry employees in continuing education programs,
students enrolled in an university degree program,
people interested in continuing education.

Taking into account the different user groups and the results and experiences of traditional learning and teaching, three principal learning scenarios can be identified (see also Section 2.4.2, Required Learning Scenarios):

- individual learning scenario
- group learning scenario
- lecturing scenario.

These scenarios will be described and analyzed in the following subsections. In an additional subsection, user requests for on-demand assistance and guidance during a learning session will be covered by the description of tutoring support.

The following references provide a good overview of the current state of the art of IT-based learning: [9, 13–15, 23, 24].

3.2.1. *Individual learning scenario.* In the individual learning scenario, the learner works on his/her own at the time and place of his/her own choice and does not communicate with other learners. The only communication taking place is asynchronous communication in the form of news groups, frequently-asked question (FAQ) listings, and bulletin boards.

Individual learning requires personal adaptation of course flow. This is supported by data collected by the system on learner performance and individual characteristics and preferences (the user's profile).

The individual learning scenario has three separate forms: the 'on-line' scenario, the 'off-line' scenario, and the 'hybrid' scenario (systems like Oracle's OLA support the first two scenarios). In the first form, the learner establishes an on-line connection to the ITBT system and gets access to the complete amount of learning material thus provided. The second form gives the learner access to learning material only from an 'off-line' medium like a CD-ROM, but it does not provide a direct connection to the on-line ITBT system. With the exception of the on-line retrieval functionality and access to

virtual labs, the 'off-line' scenario can turn into the 'on-line' scenario with features like on-line inquiries enabled if a connection to the ITBT system can be established. In the 'hybrid' scenario the learner gets material from a local source, e.g., CD-ROM, while updates and/or structuring come from on-line connections.

The individual learning scenario is not targeted at a special user group. It can be used by all user groups mentioned above.

3.2.1.1. On-line Scenario

The on-line form of individual learning gives the learner full access to the various features of advanced 'media tech', including individual access to learning materials with interaction, testing, and exploration (compare with other on-line providers, e.g., London Guildhall University [6], Christopher Newport University [13], Metro State College [14], and Athena University [15]). In addition 'media tech' offers:

access to virtual labs, including micro-worlds, animations, and simulations,

access to asynchronous communication facilities (e.g., FAQs, news groups, bulletin boards), to support group projects, to discuss ITBT and learner-generated materials, and to build a group identity,

on-line journals, electronic magazines, and online libraries for literature inquiries,

on-line access to learning material by user-defined retrieval processes,

on-line applications and downloadable software, which offers learning links to stand-alone software products.

As long as the learner has established an on-line connection to the ITBT system, he/she has the ability for self-assessment to prove his/her knowledge and get direct feedback on his/her personal learning progress. Also, the learner can write personal information, such as notes and annotations, as bookmarks back into the system for later use.

Moreover, the ITBT system gathers information about the material the learner has viewed and about his/her learning progress and can, therefore, build a simple model of the learner's knowledge status. This information enables the ITBT system to adapt the amount and granularity for presenting knowledge to the user's needs and skills, by applying limited, domain-specific heuristics rather than general, artificial intelligence student-models.

3.2.1.2. Off-line Scenario

In the off-line scenario, the learner has access only to the learning material that is locally available on his/her machine. In contrast to the on-line scenario, the presentation and the arrangement of learning material is restricted in such a way that no (or very little) individual adaptation is possible. User adaptation is available only for the locally-stored information about the user and, therefore, is not persistent in the context of the ITBT system.

3.2.1.3. Hybrid Scenario

The hybrid scenario is characterized by a mixture of resources. Material and structure information may be obtained from local sources or from sources that are on-line and provide material updates and structure guidance through courseware. In this way, material distribution media do not become obsolete in the short term and updating can be done as needed, thus providing learners with the latest version of the material. Furthermore, all the additional on-line facilities are available, including tutoring support and guidance.

3.2.2. *Group learning scenario.* The group learning scenario enables several learners to work together cooperatively while taking a specific ITBT course. Group learning fosters social interaction between learners. It enhances individual and group achievement at both personal and social levels by confronting different personal perspectives.

Group learning can be either asynchronous or synchronous. When group learning is performed as asynchronous learning, every group member can learn individually on his/her own. At certain course-dependent checkpoints or by previous or spontaneous arrangement, all group members will be synchronized electronically, and a discussion among all members of the group can take place, so that there is synchronous feedback for all learners of the group.

Depending on whether group learning is synchronous or asynchronous, the system will either keep a group profile which summarizes the learning performance and characteristics of the whole group or keep individual learning profiles of each one of the group members.

Communication among the members of the group is not restricted to discussions. Additional person-to-person or person-to-group communication can even take place during asynchronous learning phases.

The scenario of group learning is shown in Fig. 6.

The group learning scenario provides the following discussion and cooperation models for the group:

debates and discussion (e.g., chat rooms), in which learners acquire knowledge and achieve understanding through arguing and justifying their opinions,

role playing and simulations, in which different learners play different roles and interact with the system and/or with each other to understand relationships,

brainstorming, in which learners try to find the problem solution by engaging in a brainstorming session together,

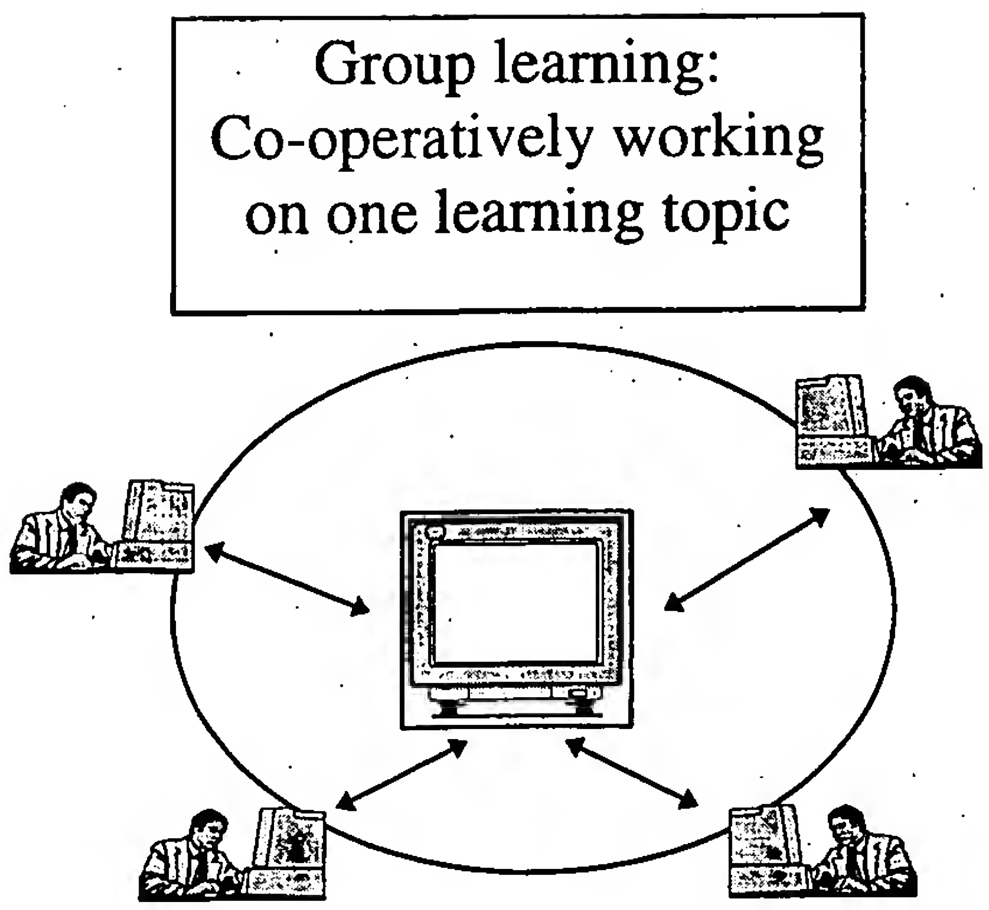

Fig. 6. ITBT group learning.

observations, in which learners cooperatively observe a given situation or themselves,

project group, in which learners learn together to solve a given situation by teamwork.

Besides the above-mentioned group internal communications, all members of the group have access to other features of the ITBT system like news groups, FAQs, bulletin boards, online journals, electronic magazines, and online libraries for literature inquiries as well as additional learning material inquiries.

This scenario is addressed especially to the university student and industry employee user groups (see also CALCampus [23], a division of the Computer-assisted Learning Center, CAL).

3.2.3. *Lecturing scenario.* The lecturing scenario derives from the traditional university lecturing model, where a teacher stands in front of a listening audience of students and explains a certain topic, but it stands in contrast to the traditional classroom in that the lecturing scenario audience is not physically assembled in a classroom. Instead, there is live participation in a virtual classroom, established by all students connected to the lecture, so that each student can choose the place appropriate for him/her.

The teacher can use any of the learning materials found in the pool of the ITBT system as well as his/her personal lecturing material, which the teacher presents to the students. Besides the more static, traditionally-oriented material, the teacher now has the ability to explain certain processes and events by drawing upon simulations and microworld interactions.

In addition, with whiteboards and tools for online retrieval, the teacher has the ability to enhance his/her prepared presentations at lecturing time and, therefore, enables the teacher to react immediately to questions from the audience.

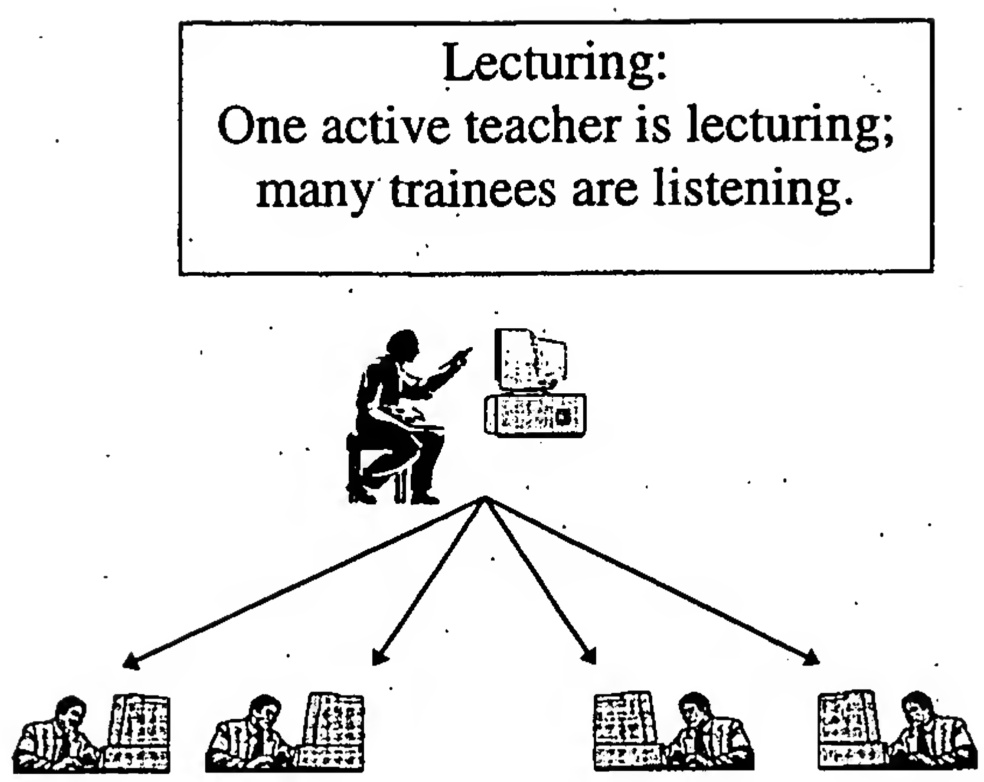

Fig. 7. Computer-supported lecturing.

The role of the students is restricted to listening but still having the ability to direct questions to the teacher, who can then decide whether to answer the questions immediately or to delay the response. The Lecturing Scenario is shown in Fig. 7.

The scenario of one-to-many broadcasting communication can be extended to a 'some-to-many' broadcasting communication needed for symposia or panels, where the active role can be handed over to a group of panel or symposium participants, while the trainees follow them from their remote sites.

This scenario is addressed especially to the university scenario for students, but it can widely be used for other lecturing scenarios, like learning via an intranet .

3.2.4. *Tutoring support.* Besides the learning scenarios described above, there is a need for assistance and advice during the learning process. To satisfy this requirement, tutoring support for the learning scenarios of individual learning and group learning must be offered. Tutoring can also be envisaged as an extension of group learning, where a member of the group assumes the special role of a tutor.

In both scenarios, a tutor can be called by a learner to get assistance and guidance. In every case, person-to-person communication between the tutor and the calling learner will be established. The tutor will then lead the trainee through the ITBT course by giving advice, assigning extra tasks, and reviewing the work performed by the trainee. This scenario is shown in Fig. 8.

For the group learning scenario, guidance for the complete group or only for a part of the group has to be available, so that the tutor can be shared among different members of a learning group.

3.3. *Course design*

Effective, high quality ITBT courses must integrate multimedia material to use the full capabilities of human perception and the potential for action (e.g., Colorado University [25] tries this by using video conferencing and real audio). Figure 9 shows

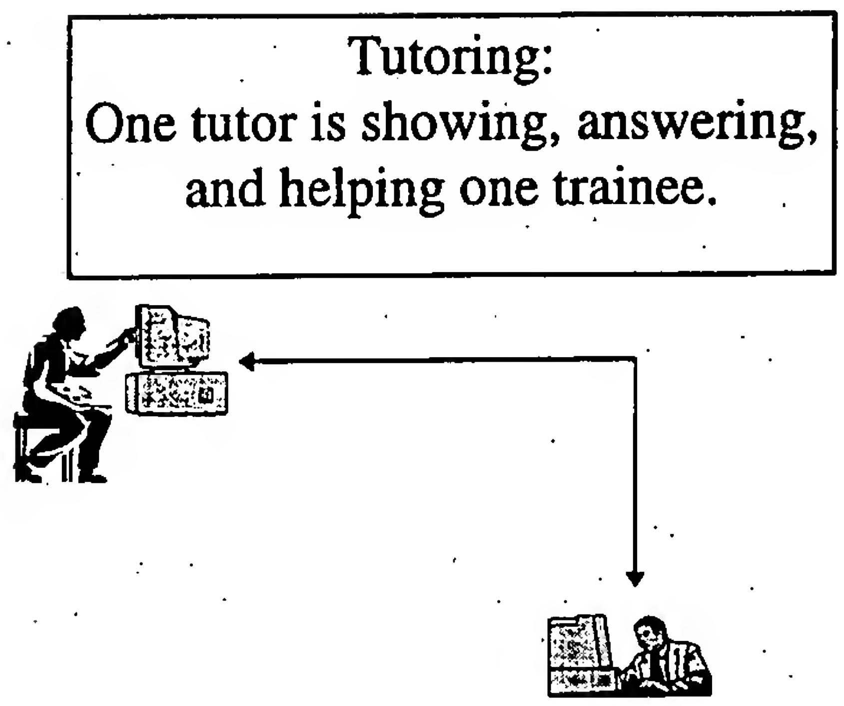

Fig. 8. Tutoring scenario.

the various information streams that must be integrated to ensure this concept.

The integration of these different streams has to be done in the light of a courseware concept that remains open to:

supporting today's standards (*de facto* industry standards as well as *de jure* official standards)

adaptability to future standards.

For this to happen, the courseware concept will have to support efficient courseware delivery as well as effective courseware creation and authoring. Smooth integration of a data storage mechanism into the runtime system will provide effective storage and retrieval capabilities to the system. The courseware concept should also be scaleable in the strict sense; that is, the course architecture should allow easy migration of already existing, traditional CBT courses or course fragments.

3.3.1. *Modularity of courseware.* Modularity of the courses is one of the most important features of the suggested course concept. This means that a course is built up from many small course modules. Like small pieces of a puzzle that together form a complete image when put together in the right way, such small course modules can be arranged in a way to form complete courses. But in contrast to jigsaw puzzle pieces, which can fit only into assigned places to make up one image alone, course modules are designed to fit into many different courses and different learning levels. This calls for a hierarchical organization that separates course contents from course structure (see next section).

To allow this modular use of the courseware units, these should be implemented in such a way that groups of modules fit together to create modules of a higher conceptual level. Course modules at the highest level then have to realize learning cycles, which are executed in learning times of short- to medium-duration. These modules are the Basic Building Blocks (BBB) of courseware.

Each BBB will follow the natural way of learning by starting with an introduction and presentation of the subject, followed by its exploration. The last step will assess the learning performance of the student and his/her understanding and mastering of the content that is the subject of the learning cycle. Self-assessment activities can be included in the BBB to assist and assure the trainee that the concepts are actually understood before final assessment takes place.

Furthermore, learners must be able to leave temporarily the learning sequence defined by BBBs and to refer to related subjects, e.g., to refresh themselves on some topic or to have a deeper look into it. These actions might be initiated by the BBBs themselves or by the learner. The result will be that the learner should be able to consult material, which might range from other modules to whole libraries either in digital or conventional formats.

In contrast to this, today's traditional university lecture phases are huge, and the direct relation between lecture, exploration, and examination is lost in most cases. Figure 10 shows both today's lecturing structure and the alternative ITBT-courseware-based structuring proposed.

Short to medium learning cycles make it possible to keep the trainee highly motivated. This is stated by Berg [26]: "Learning can be seen as a closed control loop, in which progress is reached by successful learning in small pieces (the feedback)".

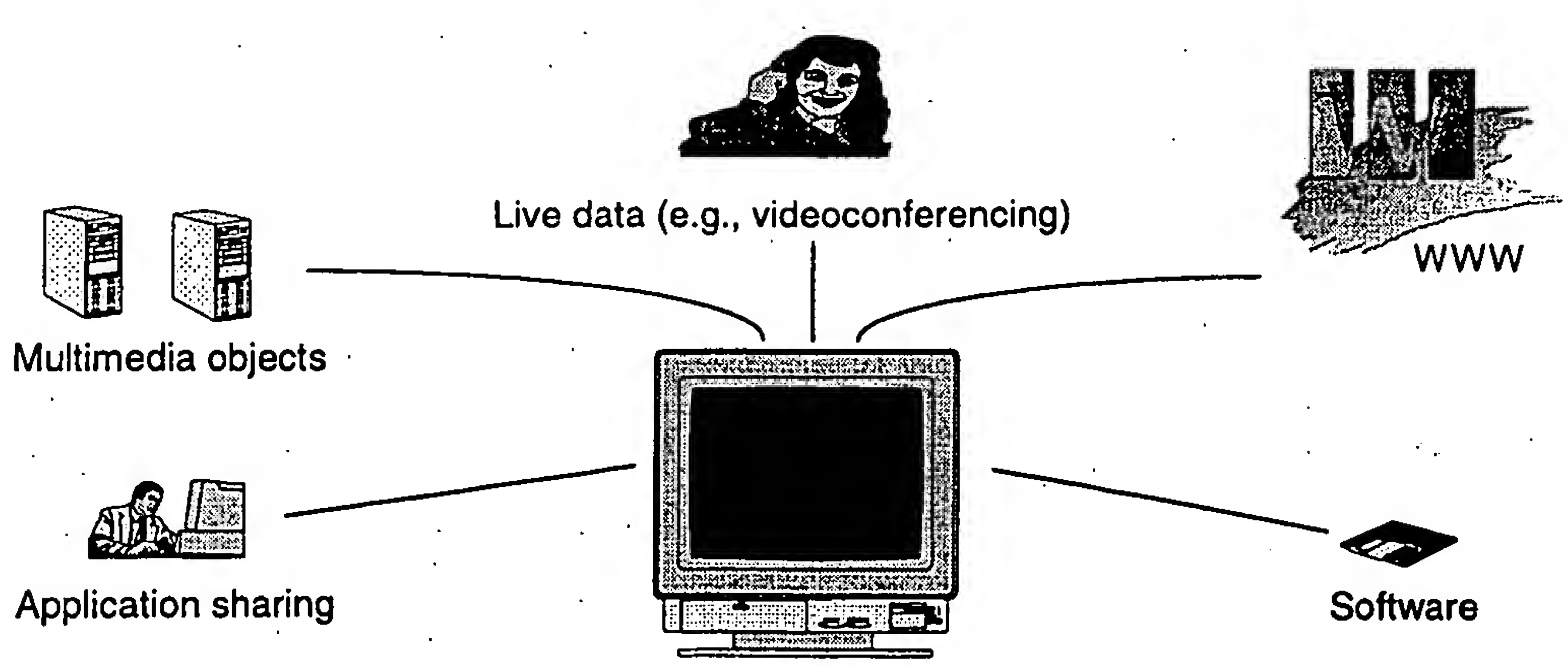

Fig. 9. Information streams that need to be integrated to ensure high quality ITBT.

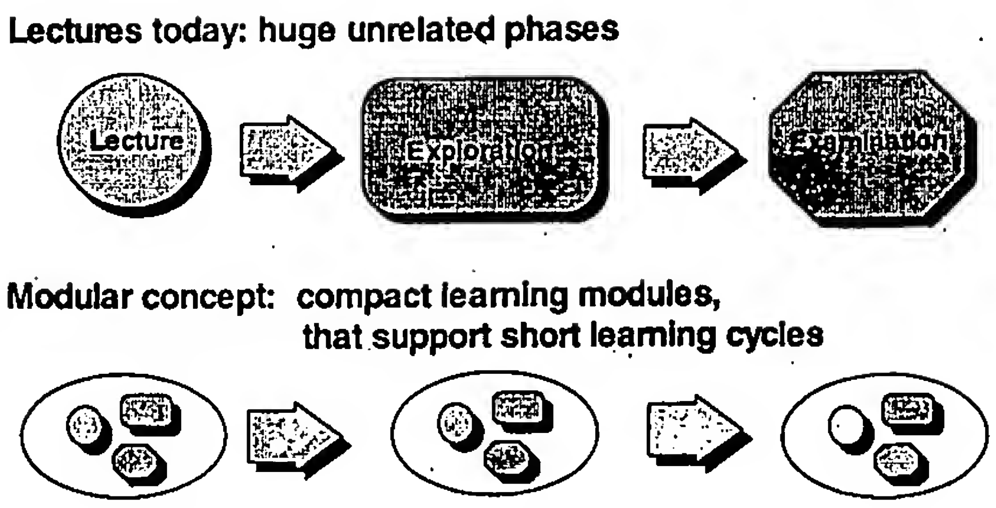

Fig. 10. Modularity of courseware.

The short learning cycles with their self-contained 'jigsaw' pieces make it easier to:

reuse modules (or BBB); e.g., if the course is updated.

use modules multiple times; e.g., in any other parallel courses on related topics.

Furthermore, the following advantages are gained:

continuous monitoring of the learning process can now be carried out with the possibility of continuous adaptation to learner performance.

learners can assess themselves and be more aware of their learning processes.

3.3.2. *Separation of content and structure*. The requirements for modularity and reuse of courseware modules lead to the need for courseware structuring in a way that lower levels carry content, while upper levels describe and organize the lower levels in a way that large courses may be composed by a static or dynamic assemblage of BBBs. This calls for descriptions attached to the courseware modules in order to be able to locate modules (see Section 3.3.3).

This leads to the very important course design process of breaking down course modules into three different types (illustrated in Fig. 11). The main difference between these different module types is how they function in the course hierarchy:

Nodes define the global structure and sequencing of course contents and its delivery to learners (nodes can refer to other nodes and/or units).

Units define how knowledge contents are presented, by defining the layout and the sequencing and interaction with the learner (units can reference only objects).

Objects are the lowest level atomic knowledge carriers, ranging from simple multimedia objects, such as graphical images, to complicated simulation environments. Closely related objects can be assembled into compound objects (see Section 3.3.4).

Nodes exist as two different types, according to their specific function: Learning Nodes and Consultation Nodes. *Learning Nodes* (LN) are organized like the branches of a tree. They span and structure the complete course into sub-branches. Learning Nodes are organized in a hierarchical way. A Learning Node can refer to other Sub-Nodes and/or Units.

Consultation Nodes (CN) differ from Learning Nodes in their function. Their aim is to determine more precisely which specific points related to the subject being learned must be addressed. Usually, they are not hierarchically organized and only refer to some Units to carry out their function.

Units fulfill the different tasks related to how and what knowledge is presented and how interaction with learners is carried out. Several different types of Units may be considered. Table 2 shows the different Unit types and their tasks.

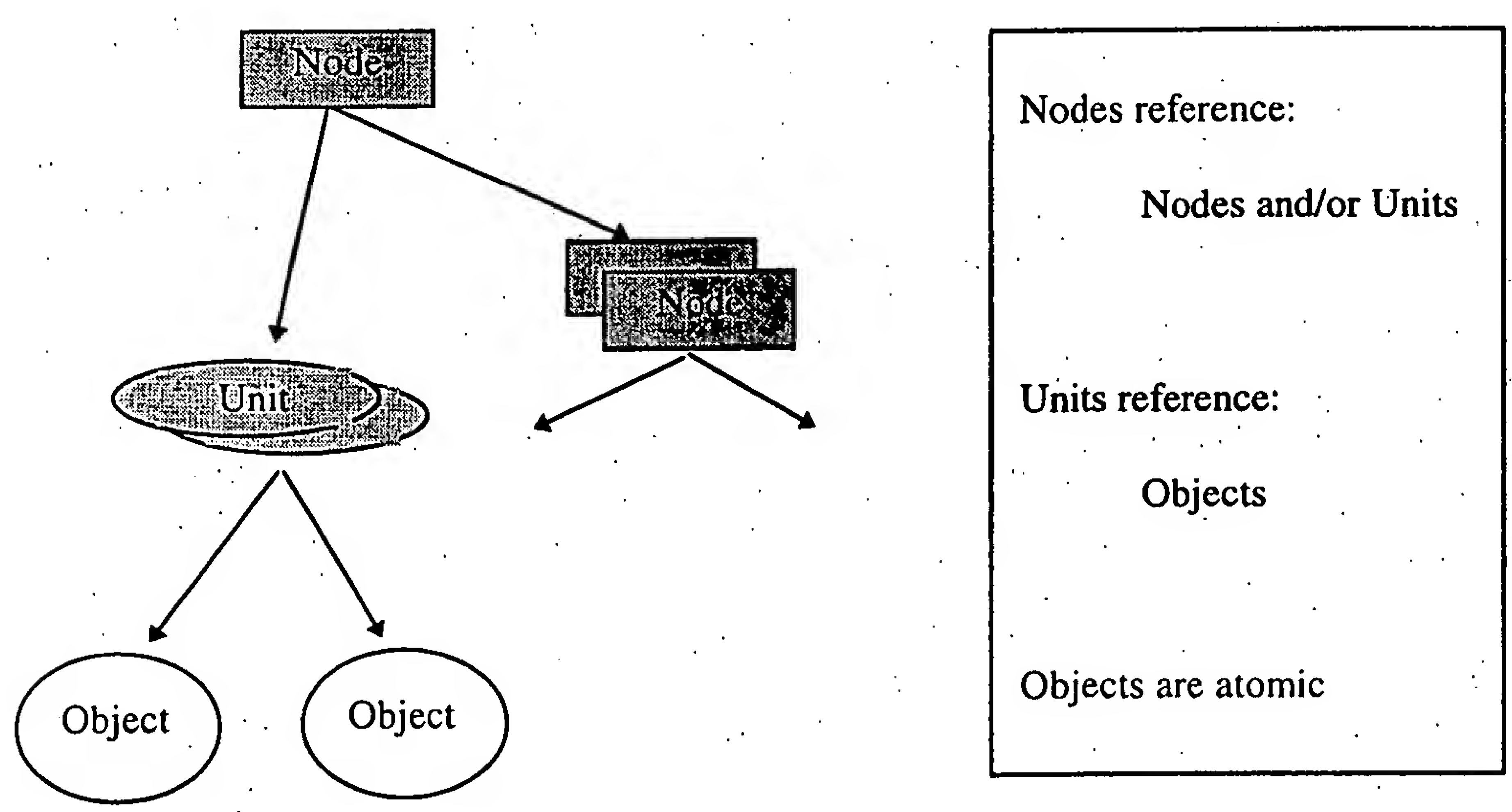

Fig. 11. Courseware hierarchy: nodes–units–objects.

Table 2. Unit types and their corresponding tasks

Unit Type	Unit Task
Information Units(IU)	Display contents, facts, and coherence. The trainee typically assumes a consuming and passive role.
Question Units (QU)	Examination of knowledge acquisition. A QU assesses whether the trainee has understood the contents. The results of QUs are considered to be reliable values for modeling users, and they influence course flow adaptation.
Action Units (AU)	Exploration and exercise environment. Exploring micro-worlds and simulations. Exercises build up like examination units with help functionality.
Selection Units (SU)	Definition and selection of learning or consultation goal. Goal definition will be based on user profile information or is selected by the user.
Presentation Units (PU)	Trainee motivation, title unit, transition unit, external references, index, and glossary of a course.

Units should not usually contain multimedia materials themselves. These materials are stored in Objects that are referenced by Units.

As mentioned, Objects are the atomic modules of courses. They include (at least) the following types of multimedia objects:

Text (with and without layout information)
Sound (speech; music)
Graphics (natural images; computer-generated graphics)
Video (and synchronized audio and image sequences)
Animations
Micro-worlds (simulations; access to remote real/virtual environments).

As mentioned above, Nodes exist as Leaning Nodes (LN) and as Consultation Nodes (CN). The different tasks of these two types of nodes imply a different structuring and sub-module model of reference for them.

Learning Nodes (LN) usually start with a Presentation Unit (PU) to introduce and motivate the trainee to the subject addressed by a BBB. After this, the BBB decides whether the learning goal can be reached by learning in a short learning cycle from a few Units or if it has to be reached by breaking it down into several sub-goals. This decision, performed within a Selection Unit (SU), is taken, either based on the trainee's profile, on a pre-testing of the trainee's previous knowledge, or even on a direct selection by the trainee. The execution of a Question Unit will usually terminate the selected learning sequence to assess whether the learning-defined goal was reached by the trainee. The typical structure of a Learning Node is shown in Fig. 12.

Consultation Nodes play the role of assisting trainees in the task of finding and consulting subjects either *per se* or related to the subject that is currently being learned. Consultation Nodes act as information finding agents and use Selection Units that present interaction dialogues allowing trainees to define the consultation goal. Such Selection Units may be called several times in order to allow users to interactively refine the consultation goal. After the goal is established, a short learning sequence (e.g., an Information Unit and an Action Unit) that matches the defined goal of the trainee is presented. The typical structure of a Consultation Node is shown in Fig. 13.

3.3.3. *Self-containment of courseware.* For the above consultation concept to work, it is necessary that references to units are not static within the CN. Therefore, references inserted into CNs at authoring time must be resolved at runtime. This requires that an efficient retrieval functionality is integrated into the runtime system. Such functionality has to be supported by additional information that describes/characterizes each, so that the information search process will be efficient.

This way, for each course module, be it either a Node, a Unit, or an Object, information describing the module's contents will be placed in a self-describing attachment (characterization). This description may contain information about the subjects' level of difficulty, level of complexity, and language of the modules and keywords.

Self-descriptions provide the information necessary to select the course module that best fits the generic targets set by the so-called *Virtual References*. These are indirect parametric descriptions of the attributes of the target modules that are specified at authoring time and that are resolved

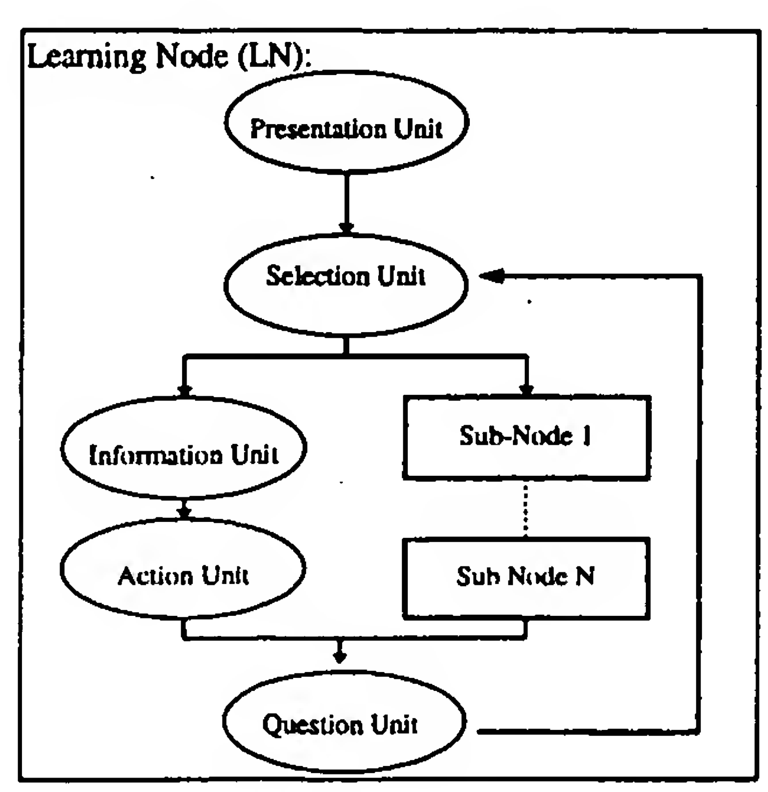

Fig. 12. Learning node structure.

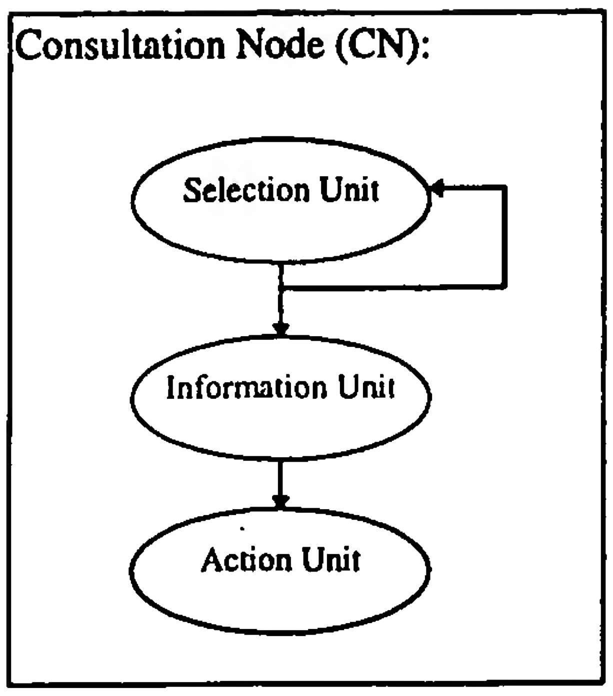

Fig. 13. Consultation node structure.

into definite Direct References at runtime. This process takes into account the learner profile.

Because all course modules are implemented together with a self-description, the following advantages are expected:

courses can be adapted/configured to specific user needs and to a learner's performance and background, thus providing dynamically adapted 'individual' views of the same courseware,

real-time, on-demand consultation can be performed,

course modules are more likely to be reused because they are easier to find,

a self-description field specifying the language (e.g., English, French, German) of a module easily supports adaptation of a course to different languages,

courses can be kept up-to-date more easily.

By supporting the efficient reuse of course content, virtual references promote both dynamic exploratory learning by students and varied questioning of the same content, thereby reducing the limitations on learning due to the 'teach and test' strategy adopted in much more conventional CBT. These two effects promote the development of more interconnected knowledge in the learner, which becomes more accessible to varied applications.

The reasons why Virtual References, together with self-descriptions, enable consultation were already mentioned. The importance of the second big advantage, a better reuse of course modules, is evident when having a look at courseware production time: estimates show that a 1 h ITBT course takes about 100–400 h of production time (see Refs [21, 22]). These figures might even be an underestimation for high-quality courseware that intensively uses video or simulations.

If the production time and cost of new modules can be reduced by using already existing modules, the above-quoted figures show the enormous potential of the concept.

To allow efficient retrieval of the different modules, one has to know the possible self-description fields and the attributes that may be given within these fields. The system supports this by different hierarchical catalogues that can be browsed by the user.

Furthermore, the number of matches into which a Virtual Reference can be mapped may be reduced by freezing the values of those fields and attributes or by reducing the range of values that such fields and attributes can assume In this way, any general-purpose course can be adapted to a specific professional group, the result being a *Configured Course*.

3.3.4. *Cross-media integration. Configured Courses* will be delivered over different distribution channels and executed under different usage scenarios, including conventional media support, e.g., paper based course notes. Therefore, courses need to adapt to actual course delivery environments. For example, a trainee directly serviced through a LAN gets the best possible multimedia presentation, including video sequences and high quality audio, because transmission bandwidth is adequate for the transmission load generated by such media. The same trainee would be able to obtain only graphics and textual presentations from the learning service, with a reasonable delay, if transmission is done over low-bandwidth networks. This adaptability is achieved by the use of *Compound Objects* that bundle different raw materials into one Object. One might think that this breaks the rule that Objects are atomic. However, Compound Objects do not contain different objects in the sense of different knowledge content. They use different media for presentation only to represent the same piece of knowledge and are, therefore, truly atomic from the knowledge point-of-view.

Compound Objects also help to answer the following problems:

How to synchronize the flow of a ITBT course with a corresponding paper handout.

How to synchronize within a ITBT course, say, an image and the corresponding textual explanation or a sequence of still images with explanatory speech.

Within a Compound Object, different raw materials can be combined together with the synchronization and sequencing information in order to answer the above questions. Figure 14 shows the concept of Compound Objects.

To allow the substitution of one material type by another one, the following requirements have to be fulfilled:

self-descriptions include the object type(s) of a Compound Object,

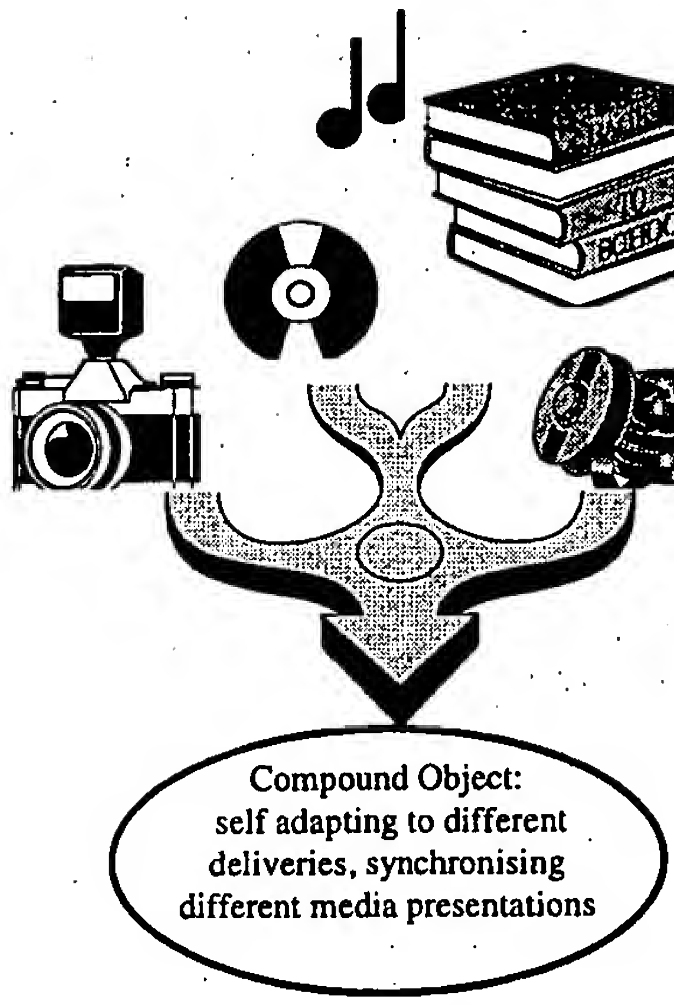

Fig. 14. Compound object.

a trainee's preferences and workplace capabilities are taken into consideration within a Compound Object.

The quality of a course is also shown by the level of its adaptability. A high quality course needs to use Compound Objects to ensure adaptability.

3.4. *Authoring support*

As mentioned above, the authoring environment is a critical key issue in a ITBT system. If the authoring environment cannot be used effectively, it can never be expected that high quality courses will be designed for any ITBT system (see also Ref. [27]).

Also as mentioned above, different authoring expert groups have to cooperate within the authoring process to ensure high quality courseware. However, it cannot be assumed that this co-operation process is synchronous in time. Therefore, it must be guaranteed that all participating groups can exchange annotations to enable teamwork within the production team. The requirements for the annotation process are determined by the different needs of each authoring group involved, in a Requirements–Task order, where each authoring group interacts with the other groups. Internal quality control should be carried out at all steps. Thus, the authoring environment can be seen also as individualized for each different authoring group; this leads to the definition of a corresponding 'Course Design Cycle' (see Fig. 15).

The different tasks and the corresponding interfaces within this authoring process are described in the following sections.

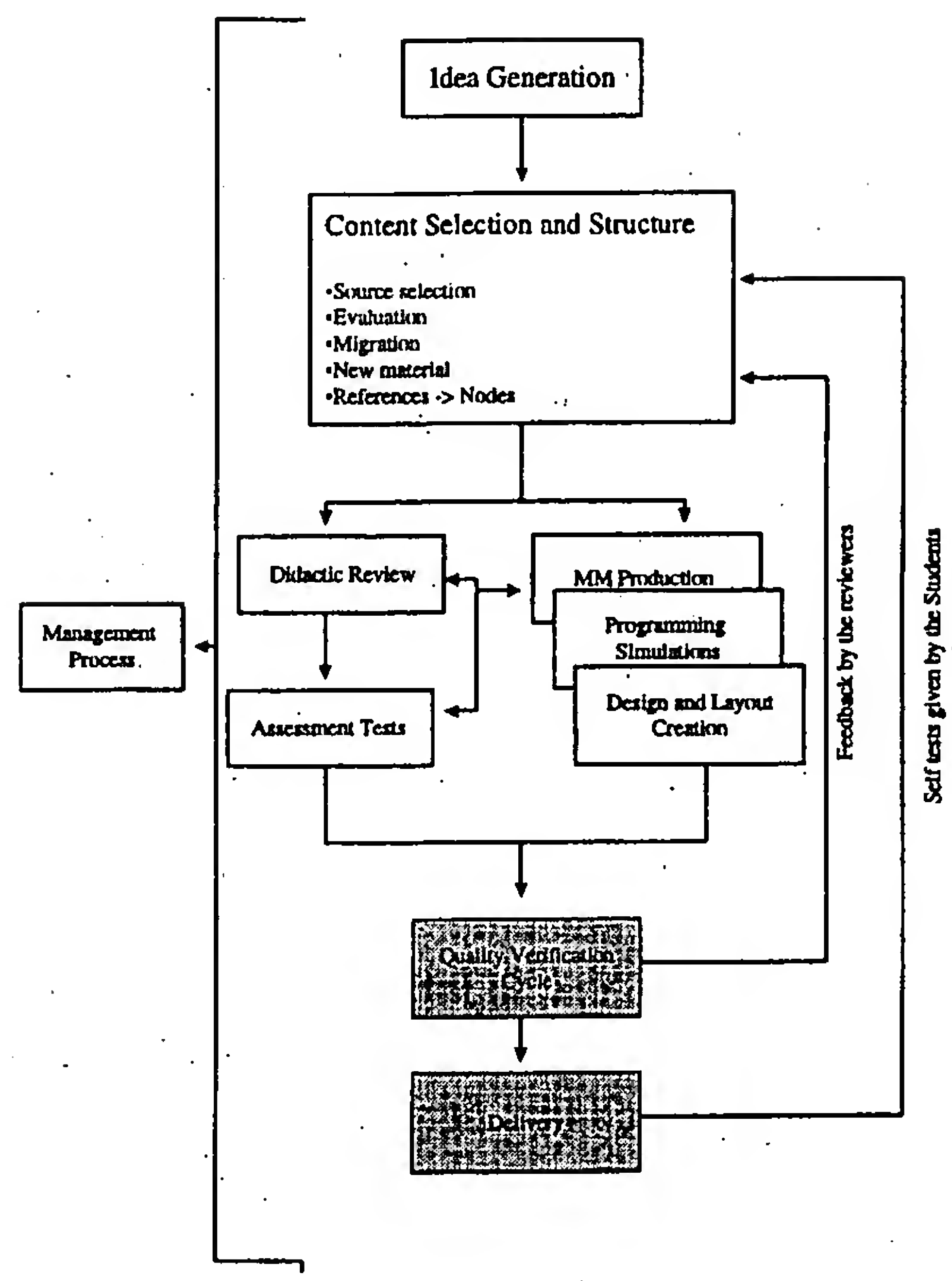

Fig. 15. Course design cycle.

3.4.1. *Idea generation/quality verification.* Course development is usually done in response to specific learning or training needs. Some person or entity responsible for the courses and the curriculum—for example, a teacher—will supervise the creation of new courses. This person/entity must also be involved in the review process of the Quality Verification Cycle to assure that the initial objectives are fulfilled.

3.4.2. *Management process.* The main function in the context of management is to secure the correct flow of data, requests, and information among the different groups. This can be done by the supervising author or by a traditional manager, who is familiar with all the tasks that need to be carried out and with all the specialists that must be involved.

3.4.3. *Content selection and structure.* The main purpose of the content selection process is to define what content has to be included in the courseware to develop and how it should be presented (compare with Ref. [28]). This process is similar to writing a scientific book. The author selects the sources first, then evaluates them, accumulates all the information, and divides the book into logical parts, chapters, sub-chapters, and paragraphs.

This phase can be carried out by Content Specialists such as researchers, teachers, professors, and industrial experts. Content Specialists do not usually have any programming background, so their authoring interface has to be based on a metaphor with which they are more familiar.

A possible metaphor could be a book-like authoring interface. The author uses this interface to divide the content into chapters, sub-chapters, and paragraphs. The description of the content can be either purely textual or specified in a more formal way, which is then transformed into References.

A more visually-oriented metaphor to perform content authoring is a tree representation. The tree view allows the same sub-structuring and the same content description as the book metaphor does, but it offers a more implementation-oriented view of the 'point of interest', of the content description, and of the corresponding breakdown while considering different levels of detail.

Content Authors who are more familiar with ITBT authoring also need the possibility of influencing the tasks of the other authoring groups. Therefore, an annotation facility will be integrated into their interface. Annotations include the group being addressed and the annotation itself. Annotations are not restricted to pure textual information; they are more sketch-pad like. Typical situations in which a Content Specialist uses annotations are:

to point out the need for some new material (videos, audio, etc.),
to influence the design and layout,
to suggest the appropriate media implementation or simulation environment,
to influence the flow of the training course.

This does not mean that a content author (as a person) can only suggest or influence the topics described above. It means only that these possibilities are integrated into the content-related authoring interface part. The content author as an individual can also change his/her authoring role and can then, for example, also implement, as a didactic specialist, the course-flow by using the authoring interface described in the next section.

One important point is the possibility of reacting on-the-fly. One example is the possibility of creating new courseware modules based on a trainee request or influenced by a trainee action.

3.4.4. *The didactic process.* Didactic aspects are one of the kernel aspects in courseware. Creating courseware requires not only top-level content material but also very good didactic presentation of the material. Therefore, there is a strong need for Didactic Review and Assessment Tests.

The main tasks of a Didactic Specialist in a Didactic Review are:

defining the course flow sequence,
refining the course structure.

The specialist should act within these tasks according to the suggested Node structure (see Fig. 12). However, the specialist can also decide autonomously how structuring should be done.

These tasks are supported by two different metaphors:

a state manager/director-oriented, time-based view,
a more system-oriented flow-diagram-like view.

Within the time-based interface, the Didactic Specialist puts the chapters/sub-chapters (in the system view, the Sub-Nodes or Units) into linear or parallel sequences. Whenever one chapter/subchapter is completed by the trainee, the specialist can decide how the trainee will then continue.

The flow-diagram-oriented interface is more closely related to system implementation. The Didactic Specialist can define directly how the different modules (Units/Nodes) are presented to the trainee during course execution. This representation is very similar to the diagram used in Fig. 12.

Besides Flow Sequence definition, it is necessary to define Assessment Tests, in which the trainee is evaluated and guided throughout the courseware according to his/her knowledge.

Both tasks (Didactic Review and Assessment Tests) must be performed by didactic specialists with a thorough knowledge of the courseware content, e.g., Professors.

Like a Content Author, the Didactic Specialist has the ability to add annotations. His/her annotations are targeted mainly at the following author groups:

Content Experts to redefine the division of the contents,
Design and Layout specialists to influence the design,
Multimedia Producers to choose the different media,
Programmers to describe the simulation and exploration environments.

3.4.5. *Design and Layout Creation.* Design and Layout Creation can be fulfilled during the authoring process or in a pre-production phase, in which corresponding templates are generated and later integrated into the authoring process.

In a cooperative mode, design and layout specialist(s) can use annotations to establish communication with other processes (specifically, to Structuring Didactic, Multimedia Production, and Programming Simulation).

Design and layout Specialists can also use annotations as cooperation facilitators. The main use of annotations should focus on communicating with the Multimedia Material Producers and Programmers, with the objective of allowing smooth integration of their objects into the interface concept.

To specify the design and the layout of a course, a graphical WYSIWYG ('what-you-see-is-what-you-get') authoring environment has to be inte-

grated into the system. The design and layout specialists need to have several standardized interface objects that are used to define the screen layout. All these interface objects need several attributes to define their concrete realization. The following list shows the different layout object types that are therefore available:

presentation areas 1 through N
title area
navigation area
status area
presentation background.

The layout and design specialists have to define the interfaces of specific modules according to the tasks of the modules. Therefore, the layout of modules with different tasks will usually be realized in different ways.

3.4.6. *Multimedia Material Production.* Multimedia Material Production itself is not integrated into the system. The task of the production itself is done by professionals who have their already well-established environments. Instead of the production itself, the pre- and post-production phases are integrated into the authoring environment.

The pre-production phase of multimedia authoring includes the following steps:

- specifying the content of single materials (e.g., text descriptions; story boards),
- specifying compound objects (specifying the relationships among single materials),
- specifying the realization of the material (e.g., data-size; resolution; native formats).

The post-production phase comprises the importing of native materials into Objects and Compound Objects. This includes the following tasks:

specifying the self-description of the Object,
defining the relationships among different materials within one Compound Object,
converting similar material types into each other (e.g., GIF to BMP, WAV to AU).

The possibility for including annotation is not as essential for Material Experts as for the other authoring groups. Material Experts mainly receive recommendations from the other author groups.

3.4.7. *Exploration and Simulation Programming.* For the Exploration and Simulation Programmers, a similar situation exists as for the multimedia experts. The programming itself will not be performed within the ITBT system environment. Again, only the specification and the import of the programmed simulators and micro-worlds is integrated into the authoring environment.

Cooperation with the other author groups is again supported by the possibility of using annotations.

3.4.8. *User interfaces.* The different authoring interfaces need to be implemented with the awareness that most authors are not programmers of any kind. An intuitive and easy-to-use interface should be designed for each of the different authoring processes.

Management Process
To allow for a global view and monitoring of the authoring process, powerful and flexible management tools are required, not only for the management process itself but also for every other technician involved.

Content Process
This is another area in which easy-to-use user interfaces are needed. Based on a book or tree metaphor, it is necessary to create/manipulate courseware structures and contents, most easily done using drag-and-drop. A graphical presentation of database contents will help with the fast previewing of the different contents. Once again, an annotation mechanism is required.

Didactic Process
Within this interface the course flow structure is defined. As in a story board, the sequencing of different, separate 'jigsaw like pieces' has to be defined. Based on a state manager/director-oriented time-based view or a more system-oriented flow-diagram-like view, this can be done efficiently. The annotation interface is nearly the same as for Content Processes.

Design and Layout Creation
As for the Content Process, easy drag-and-drop features will allow the rapid prototyping and creation of graphical layouts and designs. Special features within this interface are the template creator and template gallery browser.

Multimedia Material Production and Exploration and Simulation Programming
As mentioned above, a multimedia material production environment and a programming environment need not to be integrated into the authoring environment. Instead, an environment for post-production needs to import native materials and programmed exploration or simulation modules into the LTC. This environment also has to transform native materials into Objects and Compound Objects.

3.5. *Administration*

According to Section 2, an up-to-date IT-based Computer Training System also includes several administration tools to support installation and maintenance. If this need is not taken into account, a system will have high maintenance costs and, over time, will get more and more unusable.

3.5.1. *Installation procedure.* Three installation sites are supported:

1. Installation at the trainee's learning place,
2. Installation at the author's working environment,
3. Installation at the server site.

The installation of the trainee's learning environment should be on a 'plug and play' level. The installation procedure should be independent of the available hardware platform. The system offers an automatic configuration that enables the trainee to directly start using the system. An advanced user can individualize the system and is given this freedom within the installation process. Additionally, the system offers reconfiguration and 'uninstallation' procedures.

The installation procedure of the authoring environment is at the same 'plug and play' level as the trainee's installation. It allows similar reconfiguration and uninstall possibilities. In addition to the installation procedure of the authoring environment, one has to take care to develop recommendations regarding the installation platform and the corresponding hardware. Therefore, the installation manual shows what different platforms and hardware systems offer which authoring capabilities.

At the server site, installation can be divided into two parts:

platform and hardware selection and configuration,
server system installation.

The selection and configuration of the system platform and the underlying hardware are supported by the installation manual. The manual explicitly shows what platform offers which advantages and which restrictions, so that the administrator can select an adequate installation platform.

Server installation is done with an interactive installation process. The installation process will guide the system administrator and suggest common default values for all required configuration parameters. An installation with the default values produces a server environment that offers all commonly-used working features An optimization of the server is possible during and after installation.

The server system is also available as a completely-installed system including the system platform and the corresponding hardware. Different configurations ranging from a low-end server up to a high-end server system for several million accesses per day will be offered.

3.5.2. *Courseware administration.* Maintenance of courseware includes all courseware-related steps, such as:

releasing new versions of the courseware,
loading new courseware onto the system,
delivering courseware,
updating courseware and deleting obsolete courseware from the system.

When courseware is loaded into the system domain, the administrator defines the different access levels of this new courseware. This includes definition of the following access rights:

which trainees and trainee groups have access to the courseware,
which authors have access to include the new courseware into their courses.

Together with the access rights, access cost must also be defined to ensure correct billing.

To support different delivery scenarios, the administrator can set attributes of the courseware modules. The attributes that can be set will include the following:

local online delivery allowed,
mirroring allowed, specification of mirror sites,
off-line delivery allowed.

The update of courseware works similarly to the import procedure. All the different attributes and access rights are changeable at any point in the life cycle of a course module.

Important supporting functions of administration are the downloading and the handout service for defined course modules or even of a complete course. The download service is used if a course is distributed as a stand-alone course or if local caching of courseware has to be supported. The handout service generates the paper handouts that supplement the work with the defined course modules.

If courseware has to be deleted, the administration tools allow checking the consistency of the remaining courseware domains. Removal of mirror-copies is also taken into account. In order to find modules not referenced and modules with a low access rate, every module has an access statistic that the administration can use as a retrieval criterion.

Very closely related to the administration of the courseware is the maintenance of the attribute catalogues of the courseware self-descriptions. The administration environment contains a review and editing facility to perform the update procedures of the attribute catalogues.

3.5.3. *Learner administration.* The administration of trainees includes the creation, modification, archiving, and removal of trainee profiles. Every trainee that has access to the system has a general profile. This profile is the basis of all resources that a trainee has or which he or she can use. The general profile contains the following information:

individual system access rights,
membership in different learner groups,
definition of the trainee's learning profile,
definition of the trainee's accounting and billing information,
individual user settings (e.g., learning hard ware, learner preferences).

This implies also that additional profiles and data files have to be created and deleted by the administration software. These files include the following:

learner group profiles, which define the access rights of a group. These files can be created, edited, and deleted by the administration.
individual trainee learning profiles. This learning profile is automatically created together with the general user profile. For privacy reasons, administrative editing is not allowed.
accounting and billing information.
individual user settings.

3.5.4. *Author administration.* Administration of system authors works analogously to the administration of trainees. From the administrative point-of-view, trainees and authors differ only in their general profiles. The additional user group of tutors falls, for administration purposes, into the same user category as authors. The only difference is that some fields of the profile for one or the other group are empty. The general profile of authors and tutors contains the following additional information:

membership in author groups, which defines access to courseware of other authors and defines access rights of other authors to the courseware produced by the author.
individual name space definition.
author accounting and billing/paying information.
individualized author settings.
membership in quality control groups.
tutoring information like tutoring times, offering on-line/off-line tutoring.

3.5.5. *Cross-server site administration.* Administration also defines possibilities for cooperation with other server sites. The two main cooperation models are:

mirror sites
sites with cooperative administration of a shared courseware and user domain.

The first type of site provides an additional access point to the courseware that is mirrored. This is normally done to provide better or cheaper networking access for a special trainee group. Administration is needed only for defining synchronizing information and establishing the synchronization procedure.

The second cooperation model defines a very close cooperation between at least two server sites. The sites share their courseware, their attribute catalogues, their trainees, and their authors. From the outside they look like one server that is replicated at the different sites. But, instead of implementing the relationship as a mirror site, we now have multiple administration instances with equivalent rights that administer this scenario cooperatively.

3.5.6. *Quality control.* To assure quality control, all courseware must be peer-reviewed and certified before it is released into the courseware domain. The certification of courseware is done by a special author group, which reviews the courseware against the following criteria:

currency (i.e., if the content is up-to-date)
reusability
complexity
completeness
interaction potential
system conformance
cost/benefit ratio
correctness.

When the courseware passes the review process, the author gets a notification that his/her courseware will be released according to previously decided procedures. Otherwise, the author gets back the rejected courseware with comments on why it has been rejected.

3.5.7. *Accounting and billing.* As already mentioned, trainees and authors have an individual account where costs and earnings are registered. This account can always be viewed by the owner. On specified dates, the account is queried, and the user gets a bill or a credit. This inquiry is done by a special billing process to ensure data privacy.

An Accounting and Billing procedure on another level is the cross-server-site accounting. When server sites cooperate, they specify an accounting and billing scheme that allows a transparent way to pay or receive money for services used or supplied.

3.6. *Security*

An actual application of IT-based Lifelong Learning over the Internet requires various security measures (compare with the security mechanism at the Microsoft Online Institute [29] and CALCampus [23]). The security requirements depend on the kind of application used, on the data types, i.e., the kinds of stored/transferred information, and on the system architecture. Furthermore, the security requirements of the different actor groups in the Lifelong Learning environment (e.g., user, content provider, expert) are quite different.

For the definition of the security architecture, a risk analysis and corresponding evaluation is necessary. This analysis will depend on the application, the data, and the actors involved. Thereupon, a security architecture can be developedCan architecture which is consistent with the system architecture and integrated into the overall system.

In general, the obviously necessary security requirements are covered by:

Table 3. Protection needs versus application types

Protection needs versus applications	Authentication	Confidentiality	Integrity	Non-repudiation	Access control	Copyright protection	Restrictive use
Information retrieval	Client–server	No/optional	Yes	No	Yes	Yes	Yes
Inf. Retrieval and interaction	client–server	No/optional	Yes	No	Yes	Yes	Yes
Point to point communication	–	No/optional	Yes	No	No	No	No
1-n communication Group work		No/optional	Yes	No	No	No	No
Accounting/Billing	Yes	Yes	Yes	Yes	Yes	No	No
On-line Review	Yes	Yes	Yes	Yes	Yes	No	No
Exam	–	Yes	Yes	Yes	Yes	No	No

Authentication
Access control
Integrity
Non-repudiation (digital signature)
Copyright protection, e.g., digital watermarking [30]
Restrictive use (use control)
Accounting/Billing.

Here, the extent of application of the different security protocols and methods varies and depends on the above-mentioned factors. In Tables 3 and 4, the required protection measures are stated depending on the different types of data and applications used in the Lifelong Learning scenario.

Information retrieval

In the case of information retrieval, it is necessary that the client (or, even better, the user) authenticates itself (or himself) to the server containing the information. This step is needed to keep unauthorized users from collecting sensitive or proprietary information. In most cases it will be sufficient to transmit the data in an unprotected form. Only in the case of special requirements, will the communication need to be secured by encryption.

The integrity of the transmitted data is very important. To assure that the received information is not manipulated during transmission, the use of methods to check integrity is recommended.

Besides the extremely important point of protecting Intellectual Property Rights, there are other reasons why courseware must be protected. Courseware is rather expensive, so it is obvious that the data should be protected. Once in the terminal of the user, it is very difficult to prevent illegal copying of the data. In a non-open system, it might be possible to rely on restrictive use, but it is never easy to avoid non-authorized copying of the data. A better way might be copyright protection of the data itself.

Information retrieval with interaction

If the possibility of interaction is added to information retrieval, similar security issues occur as the ones discussed previously. Additionally, the user or client should be authenticated. Furthermore, it is important that the user is sure that he/she is connected to the desired server. This requires that there is authentication in both directions.

Point-to-point communication

If there is point-to-point communication between different actors (such as students and teachers) in a lifelong learning system, the need for secure and trustworthy authentication becomes relevant. Without any kind of authentication, the door for misuse is ajar. Furthermore, the use of methods to grant confidentially are

Table 4. Protection needs versus data types

Protection needs versus data types	Authentication	Confidentiality	Integrity	Non-repudiation	Access control	Copyright Protection	Restrictive Use
User Profile	A	A	A		A		
User Preference	U	U	U		U		
User data	U/A	U/A	U/A		U/A		
Review data	R	R	R	R	R(U)		
Courseware level 1 (raw) level 2 comp.	U	U	U		U	U	U
Courseware structure	A	A	A		A		
Accounting data	A/U	A/U	A/U	A/U	A/U		
Exam data	U	U	U	U	U		

(R = Reviewer, A = Administrator, U = User).

recommended if crucial and/or private information is communicated.

To assure the origin of the data, tools to check the integrity of the data should be present in the system.

Group work

Authentication in group work scenarios is never easy. The handling of passwords and secrets is difficult if session members join and leave the group frequently. A good solution is the use of a conference manager, which authenticates each member of a session. In proportion to the worth of the communicated information, methods for confidentially and integrity may be used.

Accounting and Billing

Accounting and billing lead the way with the strongest requirements for security. It is obvious that authentication is necessary if money for courseware is required. To secure a payment protocol, methods for secret transmission and integrity of the data must be used. To avoid a denial of services by the user, a system for digital signatures to achieve non-repudiation should be added. Billing data must be protected by access control.

On-line Review

If the work of the students is reviewed on-line, the same requirements occur as described in the accounting and billing section and should be solved with the same methods. To avoid misuse by the students and to increase acceptance by users, a system for digital signatures is strongly recommended. Access to and grading of the students' work has to be protected by access control methods to avoid unauthorized manipulation of the results.

Exam

If examinations are to be performed in such a lifelong learning system, mutual authentication becomes a necessity. Since the communications must be secured, procedures for confidentiality, non-repudiation and integrity have to be deployed. In addition to that, an access control mechanism providing identification and authentication is required.

3.6.1. *How to secure data types.*

User Profile

Current as well as completed classes of a student may be reviewed by the administrator. Confidentiality, non-repudiation and integrity are to be ensured. The data must be stored so that access control can be provided.

User Preferences

Preference settings regarding how the student's classes are presented have to be performed by the student. The security requirements are the same as in the section 'User Profile'.

User Data

Personal data of students must be accessible both to students and administrators. Integrity and confidentiality of the data is to be guaranteed in this case as well. Prior to granting access, an identification and authentication must be performed.

Review Data

Review data may only be accessed and modified by reviewers. There may be exceptional circumstances in which the students are allowed to view the data. In addition to the usual protection mechanisms, a digital signature by the reviewer is required for this type of data.

Courseware

The courseware is accessible to the students with the usual security mechanisms enforced. It should, however, only be accessible in a well defined controlled form; this implies that copyright information must be embedded in the courseware as well.

Courseware Structure

The structure of the courseware is to be controlled and administrated by administrators. The usual security mechanisms apply.

Accounting Data

Accounting Data may be reviewed by administrators as well as users. In the case of fee-based

courseware, the receipt of the courseware must be confirmed by providing a digital signature.

Examination Data

Handling of examination data is especially critical with regard to privacy issues. In addition to the usual security considerations, exercise and examination results must be authenticated and protected by the digital signatures of the students.

4. TECHNICAL IMPLEMENTATION

4.1. *Introduction*

The previous sections defined concepts and constraints for IT-based lifelong learning. These concepts have to be turned into a concrete implementation. Therefore, this section focuses on the technical implementation.

Different possibilities that were proven within the ITBT projects led by the Institutes of the International Network of Computer Graphics are described (see Appendix C, Project References). For some environments, different alternative implementations are presented. These include both commercial products and results from research projects. The final technical implementation should be chosen by the institutes and companies participating in the implementation project based on the recommendations given.

In Section 4.2, the usage scenario described in Fig. 3 is mapped to a corresponding conceptual system architecture. Estimates for hardware requirements are given in Section 4.3. The different elements of the architecture are then described in more detail in Sections 4.4, 4.5, 4.6, 4.7, 4.8 and 4.9. Firstly, basic services for data management, cooperation support and security are introduced. Then the environments used for authoring, delivery, and administration are presented.

The section is completed by addressing relevant issues for defining a concrete implementation based on the recommendations given in the previous sections. Implementation guidelines and assessment criteria are listed in Section 4.10. In the conclusion, essential aspects of the section are summed up. An implementation strategy is suggested that helps to reduce the technological risks of the implementation process.

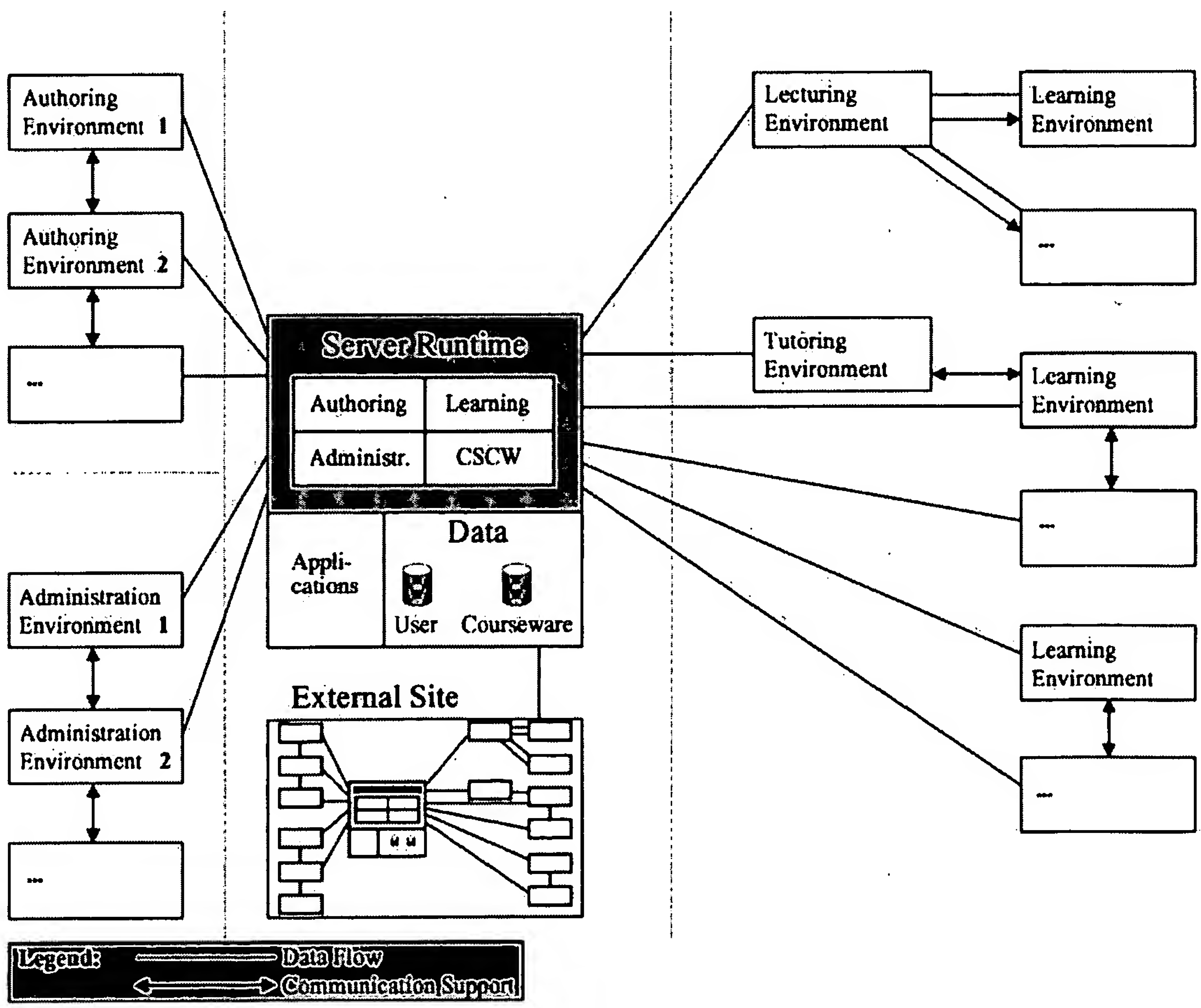

Fig. 16. Conceptual system architecture for IT-based learning.

4.2. *Conceptual system architecture*

The technical implementation has to support all types of users and all usage scenarios described in Section 3. In this section, the overall structure of such an implementation is described. Possible solutions for the different parts are then presented in detail in the following sections.

Since there are different types of users, different environments are needed to support them. An environment-oriented view of the conceptual system architecture is shown in Fig. 16. Each usage scenario is supported by its own client/server environment, but the server functionality is integrated in a central server component for all scenarios. This server component can be assumed to have a generic structure: in the top layer, it provides the different types of users with their respective runtime support. This server runtime, in turn, accesses the storage layer that handles all types of data and also handles the access to computational services (including micro-worlds and standard applications). The storage layer also handles access to data from remote sites transparently.

In addition to the different environments, basic services can be identified that are common for all usage scenarios. The most important of these are data management services, cooperation services and security services.

Actual realizations of the conceptual architecture can vary considerably depending on which types of networks are supported (LAN, WAN), how the workload is distributed between client and server runtime, and many other parameters. Existing solutions address only some aspects of the concept. Any concrete implementation of the complete environment, therefore, has to consist of a combination of several systems, tools, and specific developments.

The following paragraphs give a generic overview of core components and issues concerning the basic services and environments. Suitable approaches and solutions for the different aspects are then presented in detail in Sections 4.3, 4.4, 4.5, 4.6, 4.7, 4.8 and 4.9.

Data Management Services

Authors create courseware data, trainees access courseware data and administrators operate on user data. To do this, they access the central servers' data management services. These services allow for effective and efficient retrieval of information. The main issues are transparent access to distributed data (including the use of mirroring services), and efficient browsing and mapping tools that can be used to resolve virtual references (see Section 3.3.3, Self-containment of Courseware). Accounting and billing functionality can also be provided in direct conjunction with the data management services.

Cooperation Services

Cooperation services provide support for the cooperative authoring and training scenarios described in Section 3. They are also used in lecturing environments with two-way communication and for cooperation in cross-server-site administration.

The services consist of support for communication including video-conferencing and support for cooperative work. The latter comprises Application-Sharing, Shared Whiteboard, and Cooperative Editing. Cooperation services can be linked to specific applications more tightly to support application-specific forms of cooperation (see Section 4.8.2, Tutoring and Group Environments).

Security Services

Security Services provide access control, authentication, confidentiality, integrity, non-repudiation, copyright protection, and use restriction for the application and data types as described in Section 3.6.

Authoring Environments

Authoring environments need to support several authoring activities (see Section 3.4, Authoring Support). Essentially they comprise the following components:

- *editors for multimedia production*. These editors must also be capable of integrating different media types (e.g., linking slide shows to audio/video recordings of lectures). They should allow for a separation of layout design from the actual content.
- *design and layout editors*. Because layout is separated from content, its editing process may also be separate. Independently-defined layouts allow for reuse of design concepts in future courseware. The same contents can be combined with different layouts to accommodate different corporate designs.
- *editors for content-structuring and didactic-structuring*. Such editors are used in the content-structuring phase and the didactic-structuring phase. They need to provide authors with a flexible way of defining courseware storybooks that describe learning strategies and course adaptation to user profiles.
- *preview interfaces*. Authors need direct access to the search engines provided by the data management service. Preview interfaces allow them to browse through existing material based on virtual references (see Section 3.3.3, Self-containment of Courseware). This is important for both re-use of material and efficient tailoring of courses for specific target user groups.

In addition to the components mentioned, authors use tools provided by the cooperation service for cooperative authoring. The editors

used should be flexible in terms of the didactic strategies used for courses. This allows authors to adapt courseware individually to different cultural settings or target markets. Guidelines concerning supported data formats for multimedia authoring should be introduced as soon as the decision on a concrete implementation of an IT-based lifelong-learning system has been made.

Delivery Environments

Delivery environments rely on modules that provide the following functionality:

course runtime. The course structures and learning strategies defined by authors are applied during learning sessions by course runtime modules. They access user profiles and adapt course flow accordingly.

user profiling. User profiles are used to keep track of user interactions and test results.

format conversion. Because standard clients such as WWW browsers have to be supported, converters are needed to map the separately stored multimedia objects and layout definitions to standard formats such as HTML.

cross-media integration. Any form of education and training delivery relies on data transfer channels. The type of delivery channel used has a significant impact on the nature of the service itself and its quality. A full realization of the concepts introduced in Section 3 is only possible in a full on-line delivery scenario. But there will also be user groups with insufficient bandwidth and topics that can be taught more cost-efficiently by using off-line media. Therefore support for cross-media delivery, including off-line channels (CD-ROM, CD-I-ROM), is important. Particularly the possibility of delivering mass data through off-line channels prior to the actual learning phase is an interesting approach.

Table 5 sums up the different possible data delivery scenarios. Further differentiation can be made depending on the available bandwidth. This is reflected in Section 4.8, which presents solutions for different data delivery scenarios in separate subsections.

Administration Environments

As described in Section 2.7, administration refers to system administration (including cross-server-site administration), user administration (learners, authors and groups), and courseware administration (including quality control). To perform these tasks, the following components are needed in addition to standard tools for system administration:

- *User administration modules*. These components identify users and their roles in the IT-based lifelong-learning system. Users are given roles (trainee, tutor, author, administrator) to define the operations they are allowed to perform. They are assigned to user groups, thus defining their access rights more specifically. Users can also form groups for cooperative authoring and training dynamically. This module relies on functionality provided by the group and security services.
- *Courseware administration and release control*. Courseware administration refers to both the provision of courseware based on the distribution support provided by the data management services and release control. In order to support quality control, a defined release strategy for courseware is essential. Upon creation, courseware is considered 'private'. This state has to be changed later on, using the courseware management module, to the 'review' state and to the 'released' state.

4.3. *Hardware and infrastructure*

When the conceptual system architecture is turned into a concrete system for IT-based lifelong learning, decisions about the hardware and network infrastructure have to be made. For server sites, one has to decide which equipment to use. For remote users, minimum requirements and recommendations for hardware and available bandwidth have to be given. Nonetheless, any hardware recommendations given at one time will soon be outdated because of the ever increasing performance of standard equipment available at average workplaces. This section, therefore, focuses more on which types of hardware and infrastructure decisions have to be made and on what kind of infrastructure can be exploited in Malaysia.

4.3.1. *Network requirements*. Network access is essential for almost all usage scenarios described in Section 3. Therefore, all users of the system are expected to have some sort of network access. Nonetheless, their available bandwidth may vary. Therefore, training delivery should be scaleable

Table 5. Data delivery scenarios based on possible combinations of data transfer prior to the learning phase and during the learning phase

		Data delivery during the learning phase: none	Data delivery during the learning phase: on-line
Data delivery prior to the learning phase	none	—	full on-line
	off-line (e.g., CD-ROM)	stand-alone	cross-media delivery
	on-line	download	download with update

Table 6. Network requirements

Service:	Courseware Access		Communication	
Quality/Mode:	Cross-media deliv./ download/ download + update	Full on-line	Text-based (chat, email, news groups)	Audio-/video conferencing
Minimum Requirement:	9.600 cps	V.34 (28.800 cps)	9.600 cps	EURO-ISDN
Recommended:	V.34 (28.800 cps)	EURO-ISDN	V.34 (28.800 cps)	EURO-ISDN

with regard to the bandwidth available. As described in Section 4.2, a mixed-mode data delivery can be used to reduce network requirements for courseware access. If audio and video communication, especially video-conferencing, is to be used, the minimum requirements have to be set higher. To sum this up, the minimum requirements for network access can be set as described in Table 6.

The telecommunication infrastructure available in Malaysia is excellent: a 5 GB broadband network consisting of several 155 MByte ATM channels is available as backbone of the national Internet infrastructure. Universities have broadband connections to this backbone. Base rate EURO-ISDN is available in all major cities. Although not many customers use ISDN today, ISDN can be installed on request in companies interested in remote training. Based on this situation and the assumption that a Malaysian university will be the first server site, it can be estimated which types of users will take part in which of the usage scenarios described in Section 3.2 (Learning Scenarios) and Section 3.4 (Authoring Support). Such an estimate is presented in Table 7.

4.3.2. *Server and workplace equipment.* Requirements and recommendations for workplace and server equipment depend on the concrete implementation chosen. The information presented in the following tables has been derived from the IDEALS project (see Appendix C) and refers to the requirements imposed by the Modular Training System (MTS) developed in the project.

The MTS server is implemented for two different platforms: Windows NT and Sun Solaris. Table 8 presents platform requirements for the server system based on the project experiences.

Table 9 presents the platform requirements for authoring workplaces as defined in the IDEALS project (see Appendix C: IDEALS). Software for content structuring and the didactic process is not mentioned in the table since it is delivered along with the specific IDEALS software and is accessed by a WWW browser.

For tutors, the same recommendations apply as for authors. Concerning trainees, the requirements can be lowered, if advanced communication features are not necessary. Table 10 describes requirements for learners.

4.4. *Data management services*

Storage and efficient retrieval of courseware material created for the IT-Based Lifelong Learning System is the main issue of data management services. All data for authoring, learning, and administration are available through the database management system. All usage scenarios of the Lifelong Learning System have to be supported. Authors are supported in multimedia courseware production based on reuse of existing material, reviewers in reviewing created courseware, learners, and administrators in accessing courseware.

4.4.0.1. Database Distribution—the Virtual Training Center (VTC)

As shown in Fig. 16, each server site has its own database system. All material and information of a server site is held in its database. But several server sites are connected together and can share their database information for re-use of external material, reviewing, and teaching.

Database connectivity should be transparent for the applications accessing data management services. From an application point of view, the connected databases should behave like one virtual database. A search for specific material, for example, is automatically done over databases at all server sites. The virtual database is realized with a so-called 'distribution layer'. This is an API in the

Table 7. Dependence of usage scenarios on available bandwidth

	On-Site	At another Maslaysian university	At Industry park	At home
assumed network quality	LAN	Broadband access (Internet backbone)	EURO-ISDN (base rate)	9.600 cps
Individual Learning	→	→	→	→
Tutoring	→	→	→	text-based
Group Learning	→	→	→	text-based
On-line Lecturing	→	→	–	–
Individual Authoring	→	→	→	(→)
Co-operative Authoring	→	→	→	–

Table 8. Server equipment (based on the IDEALS project)

Type of requirement	Platform	
Operating system:	Windows NT	Solaris
Hardware:	state of the art high performance PC (min. Pentium 166 MHz, 32 Mb. Recommended: Pentium Pro 200 Mhz, 64 Mb)	high performance SunSparc
Networking HW:	Ethernet	
Networking SW:	TCP/IP (included in OS)	
WWW Server SW:	Commercial Web Server (like Netscape Enterprise Server)	
ITBT Server SW:	IT-based-lifelong-learning-system server	
Video conferencing:	Access to an MCU (Multipoint Control Unit)	
Data Management:	Database server (like DB2)	

application that gets or puts data from the application and distributes the requests to several real databases at different server sites. Material which is fetched directly by name is handled like a URL (Uniform Resource Locator). The host name is resolved and a connection is made to the server. Access to these servers could be 'read' or 'write' access. For avoiding high WAN traffic, these remote servers could be mirrored locally. Access to such copies is 'read only' for preserving consistency of material and user information. Creation or update of these copies is done by the administrator on demand to minimize bandwidth cost. Indirect retrieval of material with self-descriptions (described below) is done on all servers. The distribution layer spreads queries over the whole server table and collects the answers from the servers. Local mirrors are preferred for their fast access.

A group of server sites connected this way can provide joined services to its users. Because it looks like a single training center to the outside but, in fact, consists of a group of connected server sites, such a group is called a Virtual Training Center (VTC—see Fig. 17).

Authors working in their authoring environment can access multimedia material distributed by other authors in the Virtual Training Center (VTC) to create new course material. They can access existing pieces directly by giving their unique name, or they can search for courseware using virtual references and catalogues. Catalogues contain sets of values for the attributes used in virtual references. These values (drawn from a keyword vocabulary) are used to describe the courseware object an author is searching for. The description is given just in the same way as an author describes a newly-created courseware object in its self-description. This virtual reference created for searching is then matched against all material in the entire distributed domain of the VTC. A set of best fitting hits is presented to the author, and he/she can select a favorite. Co-authors and reviewers can also change and view this material.

From the users' point of view, there is no difference between a single server site and a VTC. They can use locally-stored and remotely-stored courseware in the same way. Training and teaching can be done everywhere in the VTC; the user is identified by his account and home server site.

Administrators are responsible only for the local database management system. They administer users, groups, access rights, and courseware in the database. There is no access for the administrator to the author's multimedia material and course-

Table 9. Equipment for authoring workplaces (based on the IDEALS project)

Type of requirement	Platform	
Operating system	Windows 97 or NT	UNIX (Solaris/SunOS 4, Irix)
Hardware	state of the art PC (Pentium 120 MHz, 32 Mb)	state of the art workstation, 64 Mb
Networking HW	EURO-ISDN or Ethernet	EURO-ISDN or Ethernet
Networking SW	TCP/IP, SLIP or PPP	TCP/IP (included in OS)
WWW Viewer SW	state-of-the-art WWW browser (such as Netscape Navigator or Microsoft Internet Explorer)	
Audio HW/SW	MS-WAVE card	shipped with OS
Video HW/SW	software player	software player
Multimedia authoring software	Standard Tools (e.g., MS Internet Assistant, Netscape Navigator Gold, ToolBook II, JDK, Adobe Photoshop,...)	
Video conferencing and Application Sharing	Equipment conforming to MBONE or H.32x standards (example: MBONE Tools plus MS-Netmeeting or ISDN-based H.32x Video Conferencing system)	Equipment conforming to MBONE or H.32x standards (example: MBONE Tools plus Fraunhofer IGD's VirtualX)

Table 10. Equipment for trainees' workplaces (based on the IDEALS project)

Type of requirement	Platform	
Operating system	Windows 97 or NT	UNIX (Solaris/SunOS 4, Irix)
Hardware	PC with average performance (minimum: 486/66, 16Mb) (preferred: Pentium, 32 Mb)	average performance workstation, 64Mb
WWW Viewer SW	state-of-the-art WWW browser like Netscape Navigatoror Microsoft Internet Explorer	
Networking HW	for individual learning: min. 9600 cps modem, V.34 modem for online communication: base rate EURO-ISDN	Ethernet
Networking SW	TCP/IP, SLIP or PPP	TCP/IP (included in OS)
Audio HW/SW	MS-WAVE compatible card	shipped with OS
Video HW/SW	software player	software player
Video Conferencing and Application Sharing	min: no video conferencing recommended: Equipment conforming to MBONE or H.32x standards (example: MBone Tools plus MS-Netmeeting or ISDN-based H.32x Video Conferencing system)	min: no video conferencing recommended: Equipment conforming to MBONE or H.32x standards (example: MBone Tools plus Fraunhofer IGD's VirtualX)

ware. They decide which server sites are available for accessing material and using external courseware. Reviewed courseware and the standardized vocabulary of the catalogues are released by the administrators, too.

4.4.0.2. Database Design And Services

The database contains all information relevant for the server site: not only multimedia material but also course layout and course structure descriptions (see Fig. 18). For a uniform description of course material, catalogues for hierarchical descriptions need to be kept too. Based on catalogues, the database can provide efficient retrieval mechanisms including the ability to perform a keyword search or a free text search.

Basic information on users, accounts, and access rights to courses are collected to support user administration. Group information for managing groups is stored as well. Authorization information is also necessary to manage users with different roles and their access rights. Accounting data are

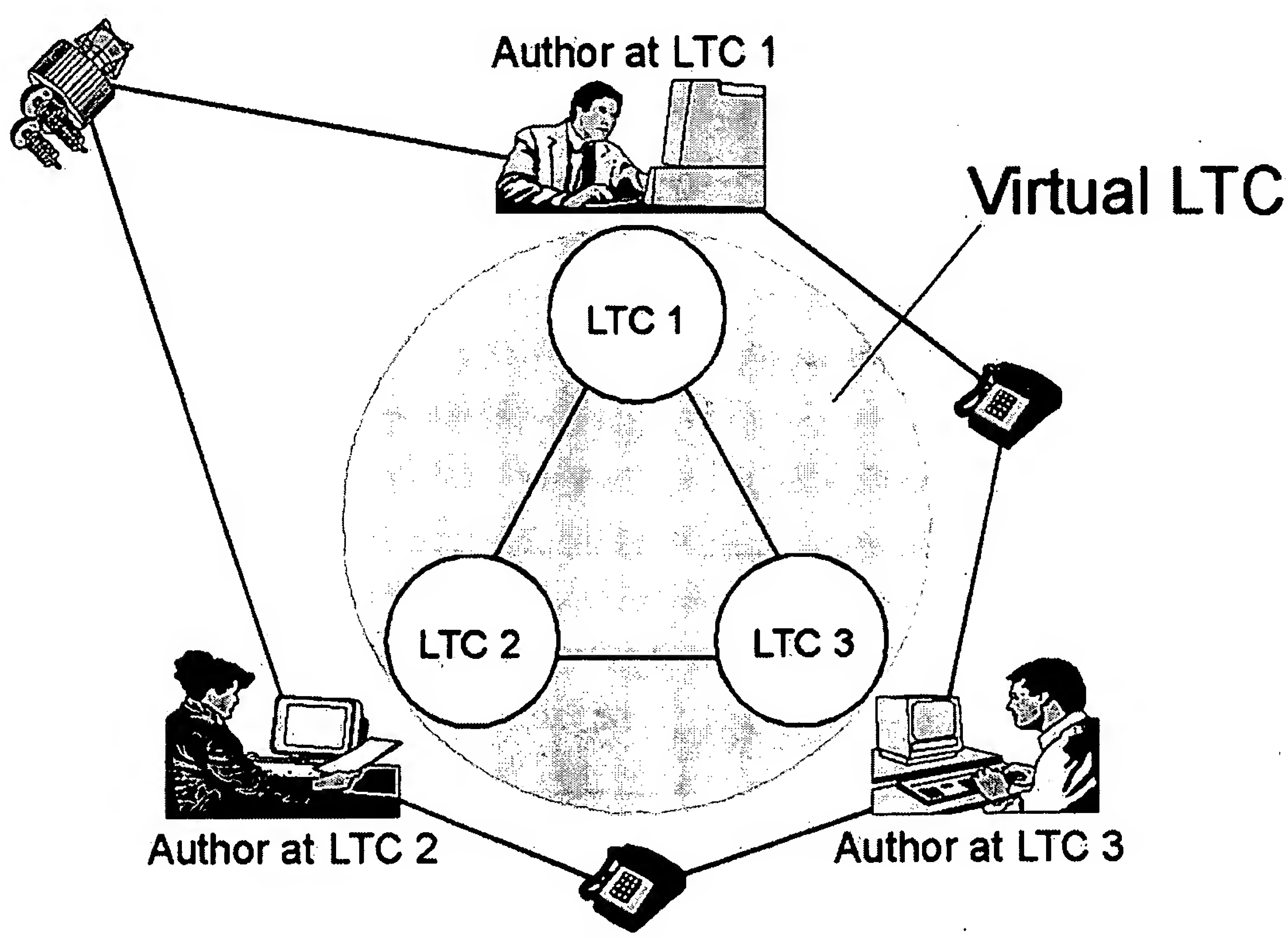

Fig. 17. The virtual training center.

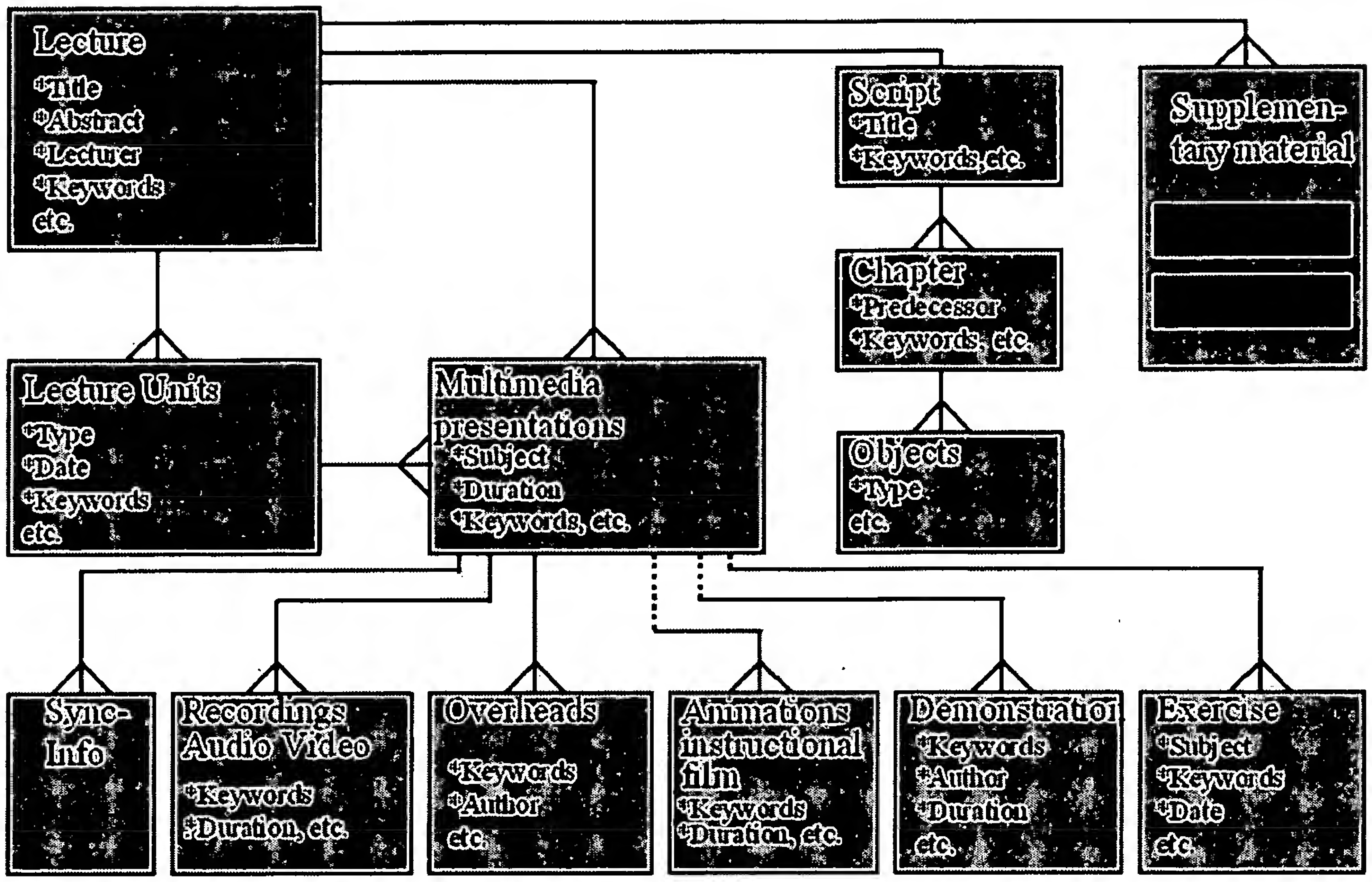

Fig. 18. Logical data scheme of the multimedia data part of a courseware database.

needed to control the users' access to courseware material and the logging of their activities. For billing, prices and costs for different courseware modules are stored. Profiles about users are held and provided to the application for evaluation of their learning effort and control of the user adaptive course flow.

Among this variety of data, multimedia courseware is the most complex to handle. Different types of data need to be stored and linked to form complete multimedia presentations. Each object is classified by attributes making up its self-description. The layout should be given as a hypermedia document, which contains links to sub-items that represent the actual data. A multimedia presentation may contain audio and video sequences and the related static data at the same time (for example, recorded lectures can be presented synchronously with the slides used in the lectures). It is, therefore, necessary to store synchronization information as well. Suggestions on how to develop and present learning material with new media are made in several articles (see Refs [31–33]).

In addition to the storage and retrieval services, data management can also be used to provide accounting and billing services based on actual access to courseware rather than login time. The services are best provided by additional modules operating on top of the database layer.

The Accounting Module collects information on user access to courseware material based on triggers from the database layer and, together with user login and logout information, transforms this into accounting records that it keeps in a temporary accounting data store. At given times, these event accounting records are sorted by user and consolidated into accounting records that are stored in the user record in the user database.

The billing module is an independent module responsible for, at given times, collecting user accounting records spanning a period of time and consolidating them into a single user billing record, given the user's billing profile. The billing module then issues a bill to the user and marks the billing record as 'due'. Administrators will subsequently change the billing record status to 'paid' using the billing module.

4.4.0.3. Data Management Services In IDEALS And TTT

The commercial database DB2 from IBM was used in the IDEALS project (see Appendix C: IDEALS). It is a Relational Database Management System (RDBMS) that is based on a client/server architecture. Special tables were created for the courseware. They contain the raw multimedia data and additional material specific information. The raw multimedia data could be up to 2 GB each. The catalogue entries for material retrieval could have up to 2 billion entries. The distribution layer, which is needed to build the VTC, was developed at IGD as a C + + API.

In the TTT project (see Appendix C: TTT), the edited material was stored in a Multimedia Database [34] developed at Fraunhofer-IGD using the commercial, object-oriented VERSANT database. Media synchronization (audio, video and

HTML slides) was performed by the system AVWOD [35] (Audio, Video and Web-On-Demand), which was developed at the Fraunhofer Institute for Computer Graphics. AVWOD uses:

- a player which is able to play *nv*-coded video streams received via UDP packets
- a player which is able to play *pcm*-coded audio streams received via UDP packets
- a web browser.

For video, a great amount of storage capacity is required. Video for 1 h requires about 800 Mbytes for the raw material. The amount of data can be reduced later by applying compression techniques. A third-level storage medium (5 Terabyte capacity) was provided for archiving raw material.

4.5. *Cooperation Services*

Cooperative authoring and learning scenarios (see Section 3.2.2, Group Learning Scenario, and Section 3.2.4, Tutoring Support) depend mainly on using additional tools for communication and cooperation, and they can be enhanced further by integrating user- and group-management components into the server runtime. Cooperation support can therefore be implemented as a cross-service.

Communication

Multimedia communication is normally defined as the usage of different communication media, such as text, audio and video, to facilitate intra-group communication. These media can be used simultaneously or separately depending on the cooperative work being accomplished. For example, the realization of tele-meetings requires primarily good audio and video communication to improve the sense of tele-presence within the distributed group involved. Audio quality, more than video quality, normally dictates the success or lack of success of the related tele-meeting, because it is the most intuitive way of human-human communication. In fact, video is usually employed to enforce the tele-presence level by bringing into the tele-meeting the visual aspect of the participants.

Asynchronous communication via email and news groups can be realized easily with clients integrated into standard WWW-browsers. Despite their simplicity, these communication channels can have a significant impact on student motivation.

Synchronous communication and cooperation via audio or video channels requires additional tools and higher bandwidth (base rate EURO-ISDN or higher is recommended). For these types of communication, the integration of IP-based software such as the MBONE tools is recommended. These tools are available for several operating systems and are able to share their network connection with the WWW-browser. Because WWW browsers are available also for all relevant platforms, the client software is practically platform independent.

When using ISDN-based communication tools, compliance with the H.32x standard is important. Otherwise, interoperability with products from other vendors cannot be ensured. ISDN tools usually require a complete communication line for themselves. A second network connection is then needed for WWW access. This is a problem for all scenarios in which communication occurs simultaneously to courseware access. It is therefore recommended to select products that support TCP/IP based conferencing as well (for example, Intel ProShare or Teles). These products can then be used for LAN-communication as well as for communication over ISDN.

It should be ensured that communication software supports multicast, because multicasting dramatically reduces the network load in group communication scenarios. Multicasting usually requires separate software to be installed at the server site. It is called a reflector or a Multicast Control Unit (MCU).

Cooperation

Cooperation software should provide the following functionality: Application-Sharing, Shared Whiteboard, and Cooperative Editing. Shared Whiteboard or Cooperative Editing environments enable groups to share a document or set of documents while following a common discussion. The documents can be made up of different formats and combinations of them, such as text, graphics, CAD drawings, raster images, HTML-files, or even software source code.

The cooperative editing process is normally implemented through the use of multi-user interface strategies in order to maintain, as much as possible, a strong group awareness. That is, group members must be aware of each other's actions.

The management of people and their actions (possibly concurrent ones) within the system is supported by specific group-coordination strategies, such as social roles, group information, maintenance of accessing rights, or well-defined sub-groups. The cooperative environment must be able to avoid prohibitive behaviors while furnishing a satisfactory level of user autonomy.

Multi-user interfaces integrate specialized HCI techniques such as personalized multi-cursors, tele-pointers, usage of different colors to express editing status, commenting mechanisms, etc. The multi-cursor technique enables an intuitive way to recognize within the group the different editing actions of its members. On the other hand, a tele-pointer is a mean of directing the attention of the group to a particular location. A tele-pointer is normally a big cursor (e.g., a logo) which

shows the editing position of its user-owner. The other users, who are receiving the tele-pointing, are forced to stop their actual work and passively follow it.

Unfortunately, today's application-sharing systems are tied to specific Graphical User Interfaces such as X-Windows, MS-Windows, or OS/2 Presentation Manager. In the COBRA-3 and IDEALS projects, it was, therefore, decided not to support cross-platform application sharing. Microsoft Netmeeting for MS-Windows and Fraunhofer IGD's VirtualX for X-Windows are IP-based application-sharing systems used in these projects.

Example—the IGD's VirtualX System

VirtualX is a cooperative multimedia environment developed to support distance training of X-Windows applications. It allows small teams of up to ten participants, which might be geographically distributed at remote workstations and connected over a network, to share their own local workspaces while pursuing together a common training framework.

VirtualX supports multiple-sharing facilities for the integration of complete stand-alone environments. That is, people can start and operate their own local workspaces inside of the VirtualX environment and make them subsequently *sharable* to other group members. The implementation of the multiple-sharing paradigm is based on the *virtual-screen* technique, which allows the simultaneous distribution and control of different workspaces among several distributed workstations.

VirtualX provides group awareness by allowing the traditional paradigms of co-operative editing, such as personalized multi-cursors, WYSIWIS (what-you-see-is-what-I-see), social roles, user identification, tele-pointing, specific multi-user interfaces and multi-user communication. Additional annotation features are available permitting a commenting process on the shared documentation.

4.6. *Security services*

The need for security in different application scenarios has been described in Section 3.6. In principle, security can be supplied at the level of:

- the network and the respective protocols
- the system
- the application
- the data.

These levels, however, do not exclude, but complement, each other. Several security provisions might be done both on the network and the protocol level. Some security requirements, however, cannot be met on this level, like the deliberate setting of a digital signature, the authentication of the actual user, or the specific cryptographic treatment of images and video, the protection of the intellectual property of multimedia data (e.g., copyright protection via digital watermarking), and restricting the use of the courseware. For these application-, data-, and user-specific requirements, expedient and adequate solutions can be found only on the application and data levels.

For the provision of authentication, confidentiality, integrity, access control, and non-repudiation, a set of well-defined protocols and methods exists. The existing tools (hard- and/or software) have to be integrated into the overall system architecture. Additionally, appropriate organizational and technical means for key-management and certification have to be provided.

Control of the usage of multimedia courseware on the receiver's side is necessary to a certain extent. A specific rendering process (filter) could be installed on the user side:

- To control which use-rights (e.g., print, display, copy) for which piece of information the user has.
- To account, monitor, and trace the usage.

On the content provider side, the information has to be prepared for controlled distribution. This means that the multimedia data have to be marked, encrypted, signed, and encapsulated. On the user side, only the specific device can handle and use the prepared and protected information. This device can be implemented in software and/or hardware and can be integrated as a plug-in module to the user's application (e.g., a WWW browser).

Once in possession of the information (e.g., by means of authorized copying), there is no further protection possible, except to mark or label the multimedia data. A digital watermark can discourage illicit copying and dissemination of (proprietary) information by making misuse traceable and by providing evidence of misbehavior. By embedding information about the ownership, rights, etc., proof of ownership is possible. By embedding information about the authorized recipient, the distribution path can be tracked.

4.6.1. *General security aspects*. The final security architecture and the integration of the corresponding security protocols and methods have to be defined as a function of the system architecture of the lifelong learning environment. The expected protocols are described below.

Authentication

There are many ways to proceed with authentication. The most popular way is authentication by password. A much more secure way, where the user authenticates the server and the server authenticates the user, is two- or three-way authentication described in the X.500 directory

service (Part X.509) [36]. With the use of public-key systems, messages are exchanged between server and user to prove identity. None of these messages contains readable information that would allow an eavesdropper to collect information to fake such an authentication. If confidential communications are wanted, this protocol allows distributing a secure key for encrypted transmissions.

Confidentiality

Confidentiality is needed every time secure data needs to be transmitted. There are two ways to achieve confidentiality: (1) to use a secure channel (which rarely is truly secure!) or (2) to create a virtual secure channel by the use of encryption. Encryption algorithms may be divided into two classes: symmetric and asymmetric encryption. Asymmetric methods are much more secure but need immense computing power. The common way is to create a short-term symmetric key and exchange it with asymmetric methods as described in the section on authentication. The communication itself is secured by the short-term key and symmetric methods. Because the use of cryptographic tools is always hard for non-expert users, there is a need for security platforms that make using security transparent for the users. A possible architecture is described in many publications (e.g., Ref. [37]).

Integrity

In many cases it will be necessary to detect manipulation of data during transmission. This goal can be achieved by adding a message authentication code (MAC). Before a message is sent, a hash-value of the complete message is built. This hash-value is encrypted with a secret key and is added to the message. The desired receiver of the message builds the hash-value from the received data and compares it with the decrypted MAC. If there is no difference, the message was not manipulated during transmission.

Digital signatures

The protocol of digital signatures is very close to those of integrity. The encryption of the hash-value is done with the secret key of the sender. The receiver decrypts the digital signature (similar to MAC) with the public key of the sender (the public key may be distributed in several ways). If there is no difference in the hash-value the receiver calculates from the received data, it is obvious that the message was not changed during transmission and (more importantly) that the message was created by the sender, because nobody else has the ability to encrypt the hash-value with the secret key of the sender. Therefore, a digital signature is really proof of origin, many requirements exist for a system for digital signatures, and there is still the lack of acceptance by the legal system.

Control of use

Once the data has reached the user's computer system, preventing the creation of illicit copying becomes exceedingly difficult. The use of specialized applications which allow the user to perform only a specific array of (legitimate) operations may alleviate these problems.

Watermarking

If illicit creation of digital copies does take place, it is possible to determine both the holder of the copyright and the creator of the illicit copies. In the watermarking process, additional information is integrated into the courseware using steganographic methods. This information can only be removed or recovered if one has knowledge of a secret key.

Key management

For real-life deployment of cryptographic mechanisms, especially in the field of digital signatures, the key management system is of paramount importance. The administration and storage of the public keys (as well as the generation of key pairs) must be performed by independent organizations (also known as 'trusted third parties').

4.6.2. *Protection of intellectual property rights.* The rapid development of computer and communications technologies has caused problems associated with intellectual property rights. The traditional legal framework for intellectual property does not work with digital technology. The law's attempts to balance the rights of creators with the rights of society have been traditionally dependent on manifestations of intellectual property that were physically distinct and immutable, such as books. The resulting dichotomy between an idea and its tangible expression has provided the very basis for copyright law, until digital technology began to blur this convenient distinction. Networked digital information systems make it possible for one individual, with a few keystrokes, to make an identical copy of the original work and deliver this perfect copy to others. The ease of infringement and the difficulty of detection and enforcement of intellectual property rights in a digital world force intellectual property rights owners to look to technology to protect their interests.

It is necessary to provide technical solutions to copyright and related problems in both off-line and on-line digital multimedia services. There is a need for a complete *Intellectual Property Rights Protection and Management System* to identify copyrighted works, to track usage, to verify users, and record usage and appropriate compensation.

Two important technologies for copyright protection are emerging: control of use and digital watermarking.

The general concept of the use-control technology is to deploy a tamper-resistant device in each workstation and personal computer to perform secure processing and use control of protected content. This technology has been proposed as one major solution to copyright problems by the European Union and the United States. A number of R&D projects have been financed by the European Commission, e.g., CITED, COPICAT, AMIDE, COPYSMART. More projects, mostly in America, are being carried out in large computer and/or content provider companies.

The use-control technology does not provide protection for the copyrighted work that escapes from the use control. Another technology called digital watermarking aims to provide evidence of copyright infringement and to meter and monitor the use of copyrighted works that are located out of the controlled domain. This technology embeds hidden messages into multimedia work to designate the copyright-related information (such as the origin, owner, content, use, rights, integrity, or destinations) of the work. The embedded messages do not degrade or otherwise interfere with the quality of the original work and are difficult to detect, remove, alter, or damage without devaluing the original work. A number of R&D institutions have invested heavily in this technology. For example, since 1993, the Fraunhofer Institute for Computer Graphics in Darmstadt has developed a robust watermarking systemCa system compatible with existing JPEG/MPEG standards and one that can be efficiently implemented in codecs. The EC has also funded several projects on digital watermarking, including OKAPI [38] and TALISMAN [39].

Very recently, various systems for watermarking have been developed. These systems have taken slightly different approaches to creating digital watermarking. Each approach uses a variation of data-security technology that scatters identifying information in such a way that it cannot be reassembled without an electronic key to the code.

The Fraunhofer Institute for Computer Graphics in Darmstadt developed SysCoP (System for Copyright Protection) [40]. This is a tool that allows the information provider to embed robust, invisible copyright labels in the multimedia material for designating its copyright-related message such as origin, owner, use, content, rights, integrity, or destinations.

In order to prevent any copyright forgery, misuse and violation, the embedded copyright label with SysCoP is perceptually invisible, irremovable, undetectable, unalterable, and, furthermore, able to survive processing which does not seriously reduce the quality of the multimedia data.

However, without legal protection, this technology is not likely to be effective. One of the most important modifications to the current copyright law under way is the prohibition of devices, products, components that defeat the technological methods of preventing unauthorized use and distribution of digitized works. This proposed modification will provide a sound basis for applying 'Control of Use' technology. Although there are still no concrete proposals to accept the legal status of watermarking technology, we believe that, as the technology becomes mature and widely used and becomes familiar to legal experts, it will obtain some legal standing in a court trialCjust like fingerprinting, DNA analysis, etc.

4.6.3. *Evaluation of security applications and systems.* Information Technology (IT) has become essential to the effective conduct of business and affairs of state, and IT is becoming increasingly important to the affairs of private individuals affected by the use of IT. Security criteria are needed to develop trusted information technology (IT) products that can be used to help protect important information of the government and private sectors. IT security criteria common to Europe and North America will help broaden the market for these products and further lead to economies of scale. In addition, common criteria will help achieve the goal of mutual recognition by North American and European nations of IT product security evaluations.

For over a century, it has been standard practice to test and evaluate engineering products for their safety and compliance to specifications. This practice was started in the 19th century with steam engine boilers after the number of fatal accidents had become unbearable.

With software, no such evaluation or standardized testing takes place (with a few exceptions such as military applications). That is, users are forced to trust whatever assertions the vendor of a software product makes. Even worse, license agreements bar users from taking the software vendor to court in case some damage occurs. With physical products, such a condition would be seen as unbearable; yet, in the case of software industry, this appears not to be of great relevance.

However, as more and more applications rely on computer systems, more than just a few documents are at stake. Entire business operations come to a halt if computer systems fail for some reason. Electronic commerce and government operations are also vulnerable to such failures. Clearly, the stakes have grown tremendously over the last few years and will continue to do so.

Evaluations and international efforts

The concept of evaluation is rather simple. Given an IT product, there have to be statements as to: (1) what objectives are to be achieved by

using this product and (2) how the product fits in an overall framework of a security policy of an organization. An evaluation makes sure that the stated objectives were met and determines a level of assurance that the claims made regarding the security are met.

- *The United States*

  The earliest formal evaluation standard is the US DoD Trusted Computer System Evaluation Criteria, DoD Standard 5200.28-STD, December, 1985, better known as the Orange Book. This was strictly a military standard, and it is now obsolete as it does not cover any networked applications.

  For the first time, strict guidelines for security objectives, levels of security, functionality to achieve this and for testing were given. This evolved into the preliminary US Federal Criteria for Information Technology Security. It introduced the notion of Protection profiles, Functional Requirements, Evaluation Assurance Requirements, and Development Assurance Requirements. This standard, however, did not become a FIPS because the need for international coordination had become apparent by the time it was supposed to be ratified.

- *Europe*

  Just as the DoD was the driving force behind the Orange Book, European defense departments required standards for trusted systems. National schemes were established in France, Britain and Germany. The British body is known as the CESG; the German body is the BSI (which may be abbreviated as GISA to avoid confusion with the British Standards Institute). The German national scheme was known as the ITSK (published in 1989). All national schemes are now only of historic interest, as it became clear that a common set of evaluation criteria was mandatory, because any secure product that went through the prolonged and expensive certification cycle at one national scheme would have to undergo the same procedure for other national schemes. Given the then small market for such products and the discrepancy between development and evaluation cycles, the development of harmonized criteria was natural. The result was the 1990 Information Technology Security Evaluation Criteria or ITSEC.

  The ITSEC criteria specify the relations between the developer, an evaluator, and a certification body. The latter is usually a government agency to which an evaluator is accredited.

  The main goal of evaluation is to gain confidence that the TOE satisfies its security target. The evaluation provides a particular degree of confidence that there are no exploitable vulnerabilities. The degree of confidence gained by an evaluation depends on the evaluation level and strength of mechanisms. The higher the evaluation level, the larger is the amount of relevant information provided and used, the greater is the effort required for evaluation, and the higher is the resulting assurance.

  Fundamental to the ITSEC criteria is the separation between functionality and assurance and the further split of assurance into confidence in the correctness of the security enforcing functions and confidence in the effectiveness of those functions.

- *The Common Criteria (CC)*

  The CC are the product of harmonization of the draft US Federal Criteria and the European ITSEC criteria. As such, they do not introduce new concepts, rather they provide a detailed, common, viable basis for evaluation and mutual recognition of the evaluations. Most of what has been stated with regard to ITSEC is also true for the CC.

  Arguably, the biggest advantage of the CC is its detailed requirements catalogue. While, in ITSEC, one had to rely on interpretations of the terse specifications by the national schemes, CC tries to avoid such gray areas by being detailed and explicit wherever possible.

  To quote from the CCEB-98/011: "The aspects of IT security addressed by the CC include, but are not limited to, the protection of information from unauthorized disclosure, modification, or loss of use by countering threats to that information arising from human activities whether malicious or otherwise".

  Resistance to these three types of damage is commonly called confidentiality, integrity, and availability, respectively. The CC is also designed to be applicable to aspects of IT security that do not fall clearly within these three. The CC could be applied in other areas of IT, but they make no claim of competence outside the strict domain of IT security.

4.6.4. *Necessary actions.*

Short term

For the creation of an 'industrial strength' security architecture, an evaluation of available

tools is necessary. This is especially important with regard to so-called export versions which may be delivered with limited key spaces or other crippling limitations.

Once the decision on the tools to be used has been made, specifications for the architecture and the APIs have to be created. The selected tools have to be integrated into the life-long learning system.

Particular consideration is deserved by the key management system. Independent organizations have to be entrusted with the administration and certification of public keys. The administrative services rendered by these organizations include the maintenance of expiration dates as well as the maintenance of so-called 'blacklists' that contain information on compromised and revoked keys. During an initial testing phase, such certifications might be performed by administrative personnel.

Long term

Viewed from a long term perspective, the certification authorities must be integrated into a network which is compatible with international certification authorities. This becomes a necessity once other services (such as governmental services, financial transactions or even international shopping) are to be used. The certification services may be rendered by institutions such as banks, PTTs or K.K.I.P.

Furthermore, an evaluation of the technology used, regarding functional and assurance components, must take place. This may be done using international standards such as the Common Criteria.

4.7. *Authoring environments*

As described in Section 4.3, Authoring Support, course authoring is a complex process in which different authoring expert groups have to cooperate. Therefore, it must be guaranteed that all participating groups can exchange annotations to enable teamwork within the production team (see Fig. 15). Thus, we recommend that only one type of authoring environment with all the necessary equipment be made available to all authoring groups. When working on a specific step, the author uses the appropriate parts of the software packages that provide the view of courseware authoring necessary for this step.

As shown in Fig. 15, the authoring process consists of content structuring, didactic structuring, multimedia production, simulation programming, and design and layout creation. In the following sections, solutions for these tasks are presented.

Next, the section on Commercial CBT Authoring Systems describes currently available integrated packages, and the following sections, Sections 4.7.2, 4.7.3, 4.7.4 and 4.7.5, Multimedia Production–Didactic Structuring, address the different authoring steps individually.

4.7.1. *Commercial CBT Authoring Systems.* Conventional courseware authoring focuses on the creation of complete courses. The importance of modular and hierarchical structuring of courseware has only recently been acknowledged (see also Ref. [41]). Therefore, well-known commercial CBT-authoring systems do not support the courseware concepts introduced in Section 3 very well. In particular, they do not provide sufficient authoring support for the scenarios discussed in this paper. Nevertheless, these systems have been tested and improved for years, so it is still important to study their approaches and differences. Moreover, most of today's market leaders extend their authoring systems to support WWW authoring. Therefore, these systems can be combined with the more complete solutions presented afterwards (see also Refs [42–44]) and may be used to create courseware units instead of complete courses.

The commercial CBT systems use different approaches to support the authoring process. The following different classes can be distinguished:

script-based authoring systems:

The CBT course is programmed in a system-specific scripting language. Example system: Asymmetrix' ToolBook.

icon based authoring systems:

This class of authoring systems supports authoring with a graphical user interface which uses icons for the authoring process. The icons represent different control objects and different raw media objects. The different types of icons are defined within a built-in catalogue. Example system: Macromedia Authorware.

In the following paragraphs, the two example systems are presented in more detail.

Asymmetrix ToolBook

The latest version of Asymmetrix ToolBook is available in two different packages: ToolBook II Instructor and ToolBook II Publisher. Both have the same authoring interface, but Instructor is delivered with a CBT-specific library which contains several widgets and an enhanced Internet export mechanism. ToolBook serves a wide spectrum of different presentation tasks. The proprietary scripting language, OpenScript, is comparable in its flexibility and performance to high-level programming languages like Visual Basic. ToolBook allows the export of course fragments and specially-designed courses to the World Wide Web by converting them into HTML and Java. The limitations can, at least for some browsers, be reduced by the use of Asymmetrix Neuron, a browser plug-in similar to Shockwave.

Asymmetrix describes ToolBook in the following words [45]: "ToolBook II Instructor provides an incredible array of development features coupled with a simple drag-and-drop interface. The English-like OpenScript scripting language provides the ultimate power and flexibility, ensuring the success of any computer-aided learning environment.

Based on the tremendously successful Multimedia ToolBook CBT Edition, ToolBook II Instructor has been significantly enhanced with full support for the emerging Internet platform. Interactive learning applications may now be saved in either Windows format (TBK) or the native Internet format (HTML and Java), providing the most complete Distributed Learning solution on the market".

However, ToolBook's HTML converter leads to pure HTML courses with fixed structures. The major advantage compared to standard HTML-editors is the library of Java-applets for supporting educational interactions and testing. ToolBook's Internet feature will mainly be used by authors who want to reuse existing ToolBook presentations through the Internet.

Macromedia Authorware

Macromedia Authorware is one of the best choices for authoring multimedia applications that focus on guiding the learner. This system supports very little programming in the form of a scripting language. Instead of this, visual programming with icons arranged as flow diagrams is used. In learning mode, this flow line guides the learner through the course. The different icons available represent different functions such as displaying an object, playing back a sound or a video, setting a timer, or specifying navigation. Macromedia Authorware can import and interact with course fragments created by Macromedia Director. In addition, as with Director, the Shockwave plug-in is used to export Authorware results to the WWW.

Macromedia describes Authorware in the following words [46]: "It offers the advanced features and benefits, which professional trainers, educators, publishers, or multimedia developers need, such as:

- Intranet Delivery: Macromedia Shockwave provides the compression, streaming, and FTP services that let authors deliver richer content to end users for instantaneous playback.
- Easy-to-Use, Icon-Defined Interaction: users of any skill level can develop interactive applications quickly with the intuitive Authorware flow line and icons.
- Modular Design: with models and libraries, developers can separate content from application structure and reuse content in future applications.
- Extensive Hypertext Capabilities: create hypertext and hypermedia with ten different link types. Link to text, digital movies, graphics, and sounds or perform full search and retrieval on any text at any time.
- Data Tracking: functions and variables, from simple tracking, like percent correct, to complex paths, can be created using simple pull-down menus.
- Database Connectivity: Authorware is compatible with ODBC databases and allows the transfer of information between databases and packaged Authorware files."

As mentioned above, conventional CBT-authoring systems assume a single type of author who performs all authoring tasks. Therefore, they try to integrate all authoring tasks into one integrated authoring interface. But, for more complex authoring scenarios, separate software for the different types of authors is needed as stated in Section 2.3 Author Requirements. This need is addressed in the following sections, mostly based on experiences from the TTT and IDEALS projects (see Appendix C: TTT and IDEALS, and Refs [47, 48]).

4.7.2. *Multimedia Production.* As already mentioned in Section 3.4.6, Multimedia Material Production, the production of native multimedia material need not be integrated into an authoring environment. Authors working on these levels have already selected their favorite tools from a range of available software. Media experts use a suite of media editors for standard multimedia formats, and HTML/JavaScript/VRML editors. Because more and more applications support conversion to WWW-formats, the range of suitable programs is constantly growing. Interaction Programmers uses a software development suite for Java-, ActiveX-, and JavaScript-enhanced pages. Because these editors generate output in standard formats, it is not necessary to tie oneself to one specific tool. In general, one should avoid using proprietary data formats.

The following subsections present two examples of external Material Production. The examples cover animation production and lecture recording. After this the integration of multimedia material into Local Training Centers is addressed.

Animation production

Macromedia Director is one of the leading systems within the multimedia authoring market. The two main advantages of Macromedia Director are (1) very fast processing speed of animations and (2) easy portability among the supported platforms. Director uses a drag-and-drop development environment to allow authoring groups with no programming experience to work with the system. If more complex tasks need to be solved, Director also offers a Scripting Language, Lingo. All basic raw media objects

are managed within separate windows, and their behavior is controlled by the Director's Stage module.

Finished Multimedia projects are executed by runtime modules that are available for Windows 95, Windows NT, and Apple computers. With the support of Shockwave, a plug-in for Web Browsers, they can also be used in the World Wide Web environment.

Macromedia describes Director 5.0 in the following words [49]: "The industry standard for creating and distributing interactive applications, Director provides the power, performance, productivity, and platform support every developer needs. Director 5 makes it easy to import and integrate elements from the products included in the Director Multimedia Studio, and then orchestrate those elements into high-impact, interactive applications. The intuitive interface in Director includes the *cast*, a database of graphics, sounds, color palettes, Lingo scripts, text, video, and more; the *score*, a frame-based control window with over 48 channels; and the *script*, the editor for natural-language Lingo scripting".

Lecture recording

Recording lectures provides the basis for preparing time-shifted participation. The raw material is edited using video/audio editing software. The editing process breaks down complete lectures into smaller units. In the TTT project, the raw material was prepared using the AVID Media Suite Pro. This is a complete video/audio editing environment available for several UNIX platforms. Edited segments can be processed further to enhance quality. Then, the segments are ready to be stored in a Multimedia Database.

Video and audio recording during lectures cannot be performed perfectly, because a lecture room is not a studio and a lecturer is not an actor. Assistance from technical support personnel is necessary at all times. Furthermore, high quality data projection in the lecture room is a must. The multifunctional usage (recording and presenting on the one side and live-transmission on the other) forces any implementation to make compromises concerning quality versus vividness.

Transparencies used in lectures have to be made available for time-shifted participation as well. They can be created in electronic format by using presentation programs such as Microsoft PowerPoint or Lotus Freelance Graphics. These programs are already used by many lecturers. Although they use proprietary data formats, they also allow conversion to standard graphics formats (e.g., CGM) or HTML as well. In addition, transparencies are checked into the database and linked to the respective video clips.

Material integration into LTCs

An important step that takes place after the multimedia material creation is the integration of such material into the Local Training Center. Therefore, the authoring environment must integrate post-production support. Post-production consists of the import of native materials into the database and the transformation of the native materials into Objects and Compound Objects (see also Section 3.4.6, Multimedia Material Production). For single material Objects, this is done by importing the native material into the database and adding the necessary Self-description to guarantee the Self-containment of Courseware, as explained in Section 3.3.3.

Building Compound Objects requires the definition of the relationship between the different native materials. For example, the time shifted lectures of the TTT project are built using this concept (see also Ref. [50]). Therefore, the sequences mentioned in the subsection above (HTML-transparencies, audio and video segments) are integrated into compound objects. These compound objects are able to synchronize the different media presentations by using the AVWOD [35] system.

4.7.3. *Design and Layout Creation.* As mentioned in Section 3.4.5, design and layout specialists need a graphical WYSIWYG (what you see is what you get) authoring environment with several standardized interface objects that are used to define the screen layout. This information has then to be stored into templates in order to create the different unit types that are referenced in Table 2.

In IDEALS and DEDICATED, such a WYSIWYG environment has not been integrated into the authoring environment. Instead of this, the layout is controlled by a scripting-based Unit concept defining the layout and interaction in DEDICATED. In IDEALS, the layout and design information is integrated into Units based on extended HTML. Therefore, design and layout creation can be accomplished by using commercial products that are available for creating HTML.

An integrated design and layout interface has to be implemented following the design paradigms of well known integrated presentation environments such as Microsoft PowerPoint. Power Point has implemented the definition of the slide layout schemes in a so-called 'Slide Master'. This defines the color scheme, the different slide areas, and the appearance of standard elements. The different definitions can be reused for other PowerPoint presentations after storing them as a design template.

4.7.4. *Content Structuring.* The purpose of the content structuring process is to define the content that has to be brought into the system and how this content must be structured. Therefore, the content author divides the content into logical parts, like

chapters, subchapters and paragraphs (see Section 3.4.3, Content Selection and Structure).

A realization of a content structuring interface was outlined at ZGDV and will be integrated into the IDEALS Authoring Environment. The IDEALS Authoring Environment will then support content structuring with a tree based course creation and visualization, an integrated module search mechanism and an integrated runtime mode for previewing. The IDEALS Authoring Environment will allow a consistent representation of Course Nodes for Content Authors as well as for didactic specialists (see Section 4.7.5, Didactic Structuring). The implementation of the content structuring interface will be accessible through a standard WWW browser.

4.7.5. *Didactic Structuring*. As mentioned in Section 4.7.2, Multimedia Production, and Section 4.7.3, Design and Layout Creation, standard editors can be used to create self-contained courseware modules. These modules are checked into the courseware domain database along with a self-description to allow efficient search. But authors still need to define the course control flow between different courseware Units as outlined in Section 3.4.4, The Didactic Process. This has be done by using a special interface for didactic structuring. In the following paragraphs, the Graphical Authoring Environment used for didactic Node authoring in the IDEALS project is presented. This Authoring Environment supports the didactic structuring with a flow-diagram-based creation and visualization, an integrated search module mechanism and an integrated runtime mode for previewing. It is a part of the IDEALS extension to the WWW-server and accessible through a standard WWW browser (see also Ref. [51]).

The IDEALS Graphical Authoring (GA)

The Graphical Authoring module, depicted in Fig. 22 as a component of the Course Representation, allows editing of the active course Node. Therefore, messages coming from the WWW-client to the server are passed to the Graphical Authoring (GA) module. The GA module then operates on the current course session, which is held within the Course Flow Control Module (CFC), by using this module's internal interface. When authors want to test the node they are actually editing, they can switch to run mode and course control is temporarily handed over to the CFC. After authoring has been finished, authors can store the modified course node into the database system.

The GA module reacts to user actions like 'insert new node', 'move unit', 'resolve virtual reference', and 'show self-description'. The messages can be split up internally into two different types of messages. Firstly, there are messages that result in a change of the internal representation of the course structure. The GA does this by using the interface that is provided by the CFC. The second type of message supports authors by offering them additional information about course modules (e.g., 'show self-description' and 'resolve virtual reference'). To fulfill these tasks, the GA communicates with the Search Engine and Courseware Management.

At the client site, the user interacts with the WWW browser. The user creates messages within the WWW browser by using the authoring applet. This authoring applet transforms the user's input into messages and then sends the messages to the GA module. The messages sent are the above-mentioned ones (e.g., 'insert new node' and 'move unit').

As long as the user stays in authoring mode, all changes of the course representation within the CR result in an update of the graphical flow diagram. These updates will be performed by messages generated within the GA module that are sent to the browser's authoring applet. The applet itself then updates the graphical representation of the course node.

Because of the close interaction between the authoring applets and the GA module at the server side, only together can they build the Integrated Graphical Authoring Environment.

4.8. *Delivery Environments*

Each usage scenario imposes its own set of technical requirements on the delivery process (see Ref. [52]). Individual learning and lecturing are, therefore, presented in separate subsections. Tutoring and group learning aspects are included in these sections. Commercially-available systems usually integrate data management and server runtime aspects and do not support individual subsystems for these issues. For such systems, these aspects are therefore described along with the system.

The following section outlines individual learning analyzes off-line, LAN- and WAN-based solutions.

4.8.1. *Individual learning*. Individual Learning as described in Section 3.2.1 is fundamental for IT-based Training. Hybrid scenarios combine cross-media-delivery and download with update delivery (see Section 4.2, Table 5). Online scenarios refer to either LAN-based or WAN-based solutions.

4.8.1.1. Off-line Delivery

Off-line delivery today means distributing CD-ROMs. Courses published on CD-ROMs still dominate the courseware market. With upcoming new standards for CD-ROMs, like DVD (Digital Versatile Disk), the medium has a good chance to be attractive for years to come. CD-ROM publishing is well-known and is usually based on specific runtime software for courses created with authoring

tools such as those described previously. HTML is used less frequently on CD-ROMs, but its popularity is increasing for this medium, too. Several products support the automatic creation of HTML-based CD-ROMs from Web-sites (such as MarketSpace's WebCD). So, CD-ROMs are an established distribution channel and allow for suitable amounts of data to be used in courses. Using this medium, the usage scenarios described in Section 3.2.1 can be realized based on well-known tools and procedures.

CD-ROM-based course delivery, however, also has well-known drawbacks:

Focusing on the creation of CDs usually encourages the creation of fixed courses instead of collective courseware domains. Thus, re-use of existing courses is impeded.

Monitoring of student behavior and course usage is almost impossible for the provider. Thus, training efficiency and user acceptance of courseware cannot be evaluated automatically.

Maintenance of course installations is relatively expensive, thereby increasing the total cost of ownership.

Advanced scenarios, such as online tutoring, require network connectivity.

CD-ROMs can be appropriate where large amounts of data that need to be updated infrequently are presented to large user communities. In other cases, network delivery is a more promising approach and used by several commercial and research systems. CD-ROM can still play a role in network delivery scenarios, as an additional source of courseware data.

4.8.1.2. Hybrid Solutions

In hybrid delivery scenarios, a mixture of resources is used. Mass data, such as audio- and video-clips, are transferred prior to the actual learning session and stored locally on the user's computer. Information that is liable to change often or is generated individually for the user is transferred online during the learning session. A variety of actual implementations of hybrid scenarios can be imagined—from mostly off-line scenarios that use online connections only for transferring test results to a server site or for on-line tutoring to mostly online scenarios that maintain course structures and user profiles on the server and go off-line only to read multimedia objects from local storage. The more online components comprising the hybrid solution, the more flexible and advanced are the possible usage scenarios. Hybrid solutions that allow for setting up an online connection at any time during a session are recommended. Then, any element of a course can be replaced automatically by a more recent version from the server.

Basically, there are two types of hybrid solutions: the data transfer prior to the learning session can either be done by distributing off-line media such as CD-ROMs (for cross-media delivery, see Table 5 in Section 4.2) or by downloading the data via a network connection. The latter approach may seem somewhat complicated, but it also has its advantages:

Users with low-bandwidth connections don't have to wait too long during the learning process for multimedia data to be downloaded on-demand.

A download prior to the actual learning session can be done at a time of day when telephone charges are low and/or the network load on the Internet is low. This might be more cost effective even if some of downloaded data are not used during the learning session.

For implementing a hybrid courseware solution, different approaches are possible:

Several software companies provide proprietary solutions for mixing data read from the WWW with local data. These mechanisms can be exploited directly to realize hybrid scenarios. WWW-CD-hybrids are still an emerging market, and it is not yet clear what will be the major products in this area. The most promising product today seems to be Netscape's LiveCache mechanism distributed with the Netscape Navigator 3.0 release. This tool adds CD-ROM data to the WWW-browser's cache, thereby allowing for a seamless integration of local and downloaded material. Spyglass has similar capabilities.

A special converter on the server side can be used to transform links into local links at runtime. Then, at the beginning of a learning session, a user will specify whether a CD-ROM is used during the upcoming session. The converter is aware of the data available on the CD-ROM and will change any link to this data to a local link. The converter may also check an update table to identify which parts of the CD-ROM have become outdated and should be replaced by updates from the net. This approach requires additional implementation effort for the IT-based lifelong-learning system, but it has the advantage of being completely invisible to the end user, because it is not tied to any specific browser or tool provider.

Hybrids are compelling in concept: online WWW technology and off-line CD-ROM technology each have relevant, but complementary weaknesses. The Web is dynamic and limitless—until you try to download multimedia data along a slow telephone line. CD-ROMs are static and limited, but they do supply 650 Mb of multimedia data at high speed and can be mailed for approximately $1. A combination of the two might be able to get the best out of both delivery channels.

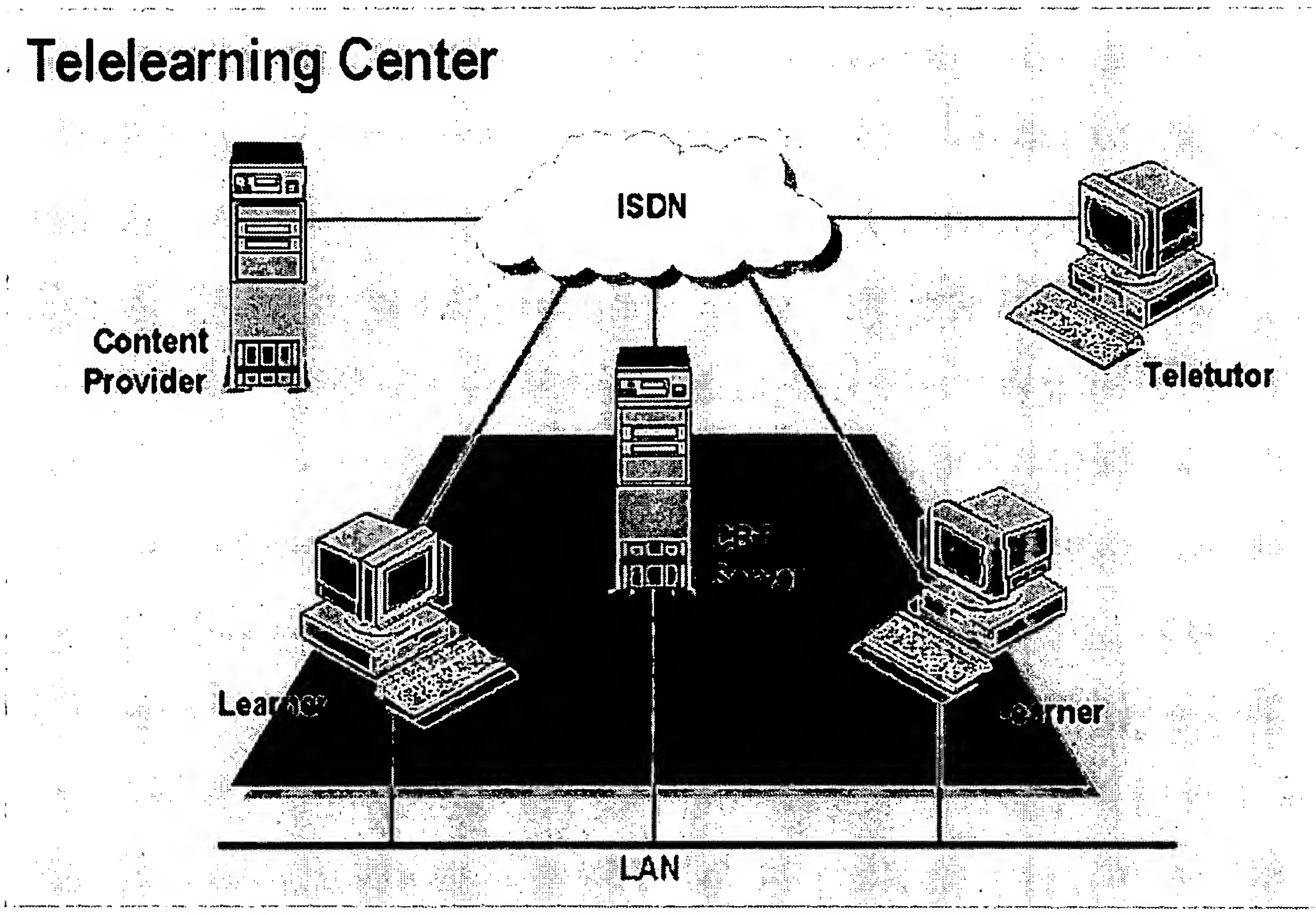

Fig. 19. Client/server architecture of SNI's tele-learning center.

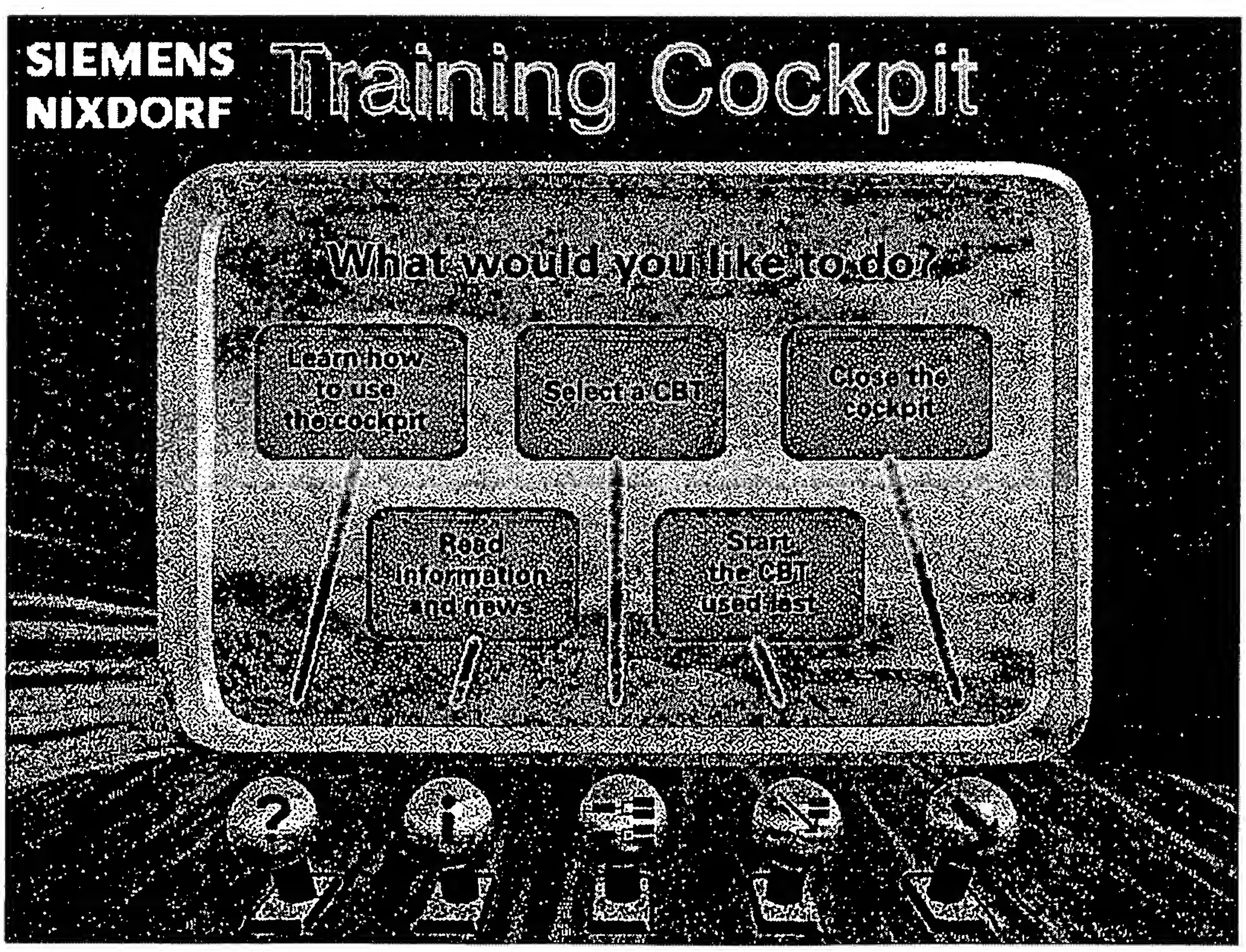

Fig. 20. Tele-learning center: training cockpit.

4.8.1.3. Solutions For Local Sites

This section presents LAN-based solutions for courseware delivery from SNI and IBM. Afterwards, a realization for time-shifted participation in lectures is presented.

Self-Learning Architecture (SLA)

The Self-Learning Architecture [53] developed by Siemens Nixdorf Informationssysteme AG (SNI) is a LAN-based training system built on a client/server architecture (see Fig. 19). It combines technology-based learning methods with personal training through human interaction. The full range of Self-Learning Architecture services comprise three building blocks: 'Introductory Consulting and Concept Definition', 'CBT on Demand', and a 'Tele-learning Center' for further education.

The core of this architecture is the CBT server with the learning contents and the self-learning management tools for managing and invoicing learning activities.

SNI's CBT-on-demand solution requires a high-performance PC with Windows NT/Server and Microsoft SQL as the CBT server and multimedia PCs with LAN boards and optional communications hardware and software as Learning PCs. A major feature of SLA is its support for distribution of the customers' own CBT modules through the CBT server. Because courseware is stored only on one or a few servers and not on all Learning PCs, courseware management is simplified significantly. *Self-learning management* (SLM) software for the CBT server is responsible for installing CBT modules, managing learning materials and users, evaluating user activities, and evaluating learning materials. On the client side, SLM provides support through the user's '*Training Cockpit*'. SLM allows for selecting learning material, obtaining demo versions, evaluating learning material, selecting a tele-tutor, obtaining information on workshops, and registering (see Fig. 20).

Tele-tutoring is supported by adding ISDN-based communications software and hardware (e.g., I-View) for application-sharing and video-conferencing.

IBM Personal Learning System (PLS)

The Personal Learning System (PLS) [54], a LAN-based CBT system developed by IBM, is an open delivery and administration environment. It supports multi-vendor courseware delivery, multiple server support, and student administration services within a single platform. The system supports distance learning with tele-tutoring and stand-alone learning using the CD delivery mode. The software architecture of PLS is based on client/server technology and is not connected to the WWW. PLS supports minimal user adaptation. It is available for Microsoft Windows and OS/2.

PLS includes only a 'mini'-authoring tool. Course authors are supposed to use their favorite authoring tool to create self-contained courses. PLS integrates such courses into its environment as black boxes. Courses can be surrounded by additional modules. With the addition of introductory or closing modules to the existing content, it is easy to add custom lessons specific to the provider's own environment while still having the flexibility of purchasing courseware that is cost-effective and meets a core amount of training needs.

PLS supports the integration of video conferencing tools such as PictureTel [55] and ProShare [56]. From within PLS a desktop video conference application can orchestrate a dialogue between students and remote coaches during a course and share lessons running under PLS (and other applications). PLS seeks to enhance the overall communication process throughout an organization by adding multimedia elements to information.

PLS can be used in multiple environments: Local Area Network(LAN), Standalone PC, and Laptop Computer. PLS can access courses from network file servers, network CD-ROM drivers, local PC hard drives, and local PC CD-ROM drives.

PLS in LAN mode is offered in three versions. Using the mode, 'Combined Analog/Digital—Two Wire Solution—For Shared LAN', digital video files stored at the server are transferred to a 'video player' (a PC with a special codec installed). In the video player, the digital video data is transformed into an analogue video signal. That analogue signal is then transferred over a coaxial cable where it is received by a PC with a TV tuner card installed. Using the mode 'Combined Analog/Digital—One Wire Solution—For Shared LAN', PLS can deliver and manage the mix of analogue and digital data over a single wire Token-Ring network with the use of IBM's F-coupler technology. The third mode is 'Full Digital Learning System—For Dedicated LANs and Learning Centers'. Digital video is transmitted over the LAN. Decompression of the signal occurs at the client PC with an attached codec card. The configuration supports concurrent MPEG digital video streams over various networks. The full Digital Personal Learning System networks are most appropriate for learning centers.

PLS in stand-alone mode, with ISDN or standard telephone line connections for non-video course distribution from a central location, is suitable for a smaller office that still needs to communicate with a central site but which has fewer employees and fewer IT resources.

Personal Learning System CD is for non-network distribution of video-based courseware. PLS CD is the combination of the Personal Learning System code and courseware together on CD-ROM.

The Personal Learning System supports user administration, course administration, and system administration. PLS provides Course Catalogue and Repository Management functions. The administration data collected is stored in the data base, with version 2.2, Dbase IV and DB2 are supported.

Time-Shifted participation in lectures in the TTT project

Time-shifted participation in lectures is a special type of Individual Learning. In this scenario, recordings from lectures suitably combined with electronic presentation material are used as courseware (see Section 3.2.3, Lecturing Scenario).

Recordings from lectures are edited and broken down in units as described in Section 4.7.2. Then, the units are ready to be stored. Because massive amount of Audio/Video data have to be stored and linked to additional presentation material, a high-performance implementation of the data management services is of special importance here.

The students can then select the desired multimedia learning material, and a WWW-interface presents the data. Students may use these facilities to take the course at individually chosen times, for individual examination preparation, as an exercise for help, or for practical training. Figure 21 presents a sample from TTT.

4.8.1.4. WAN-based Individual Learning (WWW)

Regional or even world-wide export of learning and training requires technologies different from solutions for LANs. The Internet and WWW as its multimedia user interface have rapidly reached a dominant position for WAN-based information systemsCa position they will keep for the foreseeable future (see also Refs [57–59]). We, therefore, first address the possibilities of courseware creation simply using WWW and associated technology, and then we present a more advanced system for WWW delivery that fits better the requirements introduced in previous sections.

WWW courses

Several universities and corporate training providers offer WWW courseware. The list includes prominent institutions such as the Massachusetts Institute for Technology [6] and the Gartner Group [7], as well as well-known distance learning universities such as the Open University [8], University of Phoenix-Online Campus [12], University of Hong Kong [16] and Fernuniversität Hagen [17].

Traditional universities mostly use pure HTML document collections that are best described as hyper-structured electronic versions of lecture scripts. This approach helps students find information on specific topics more easily. But, for complete lectures, students usually prefer to print out the text and study it on paper.

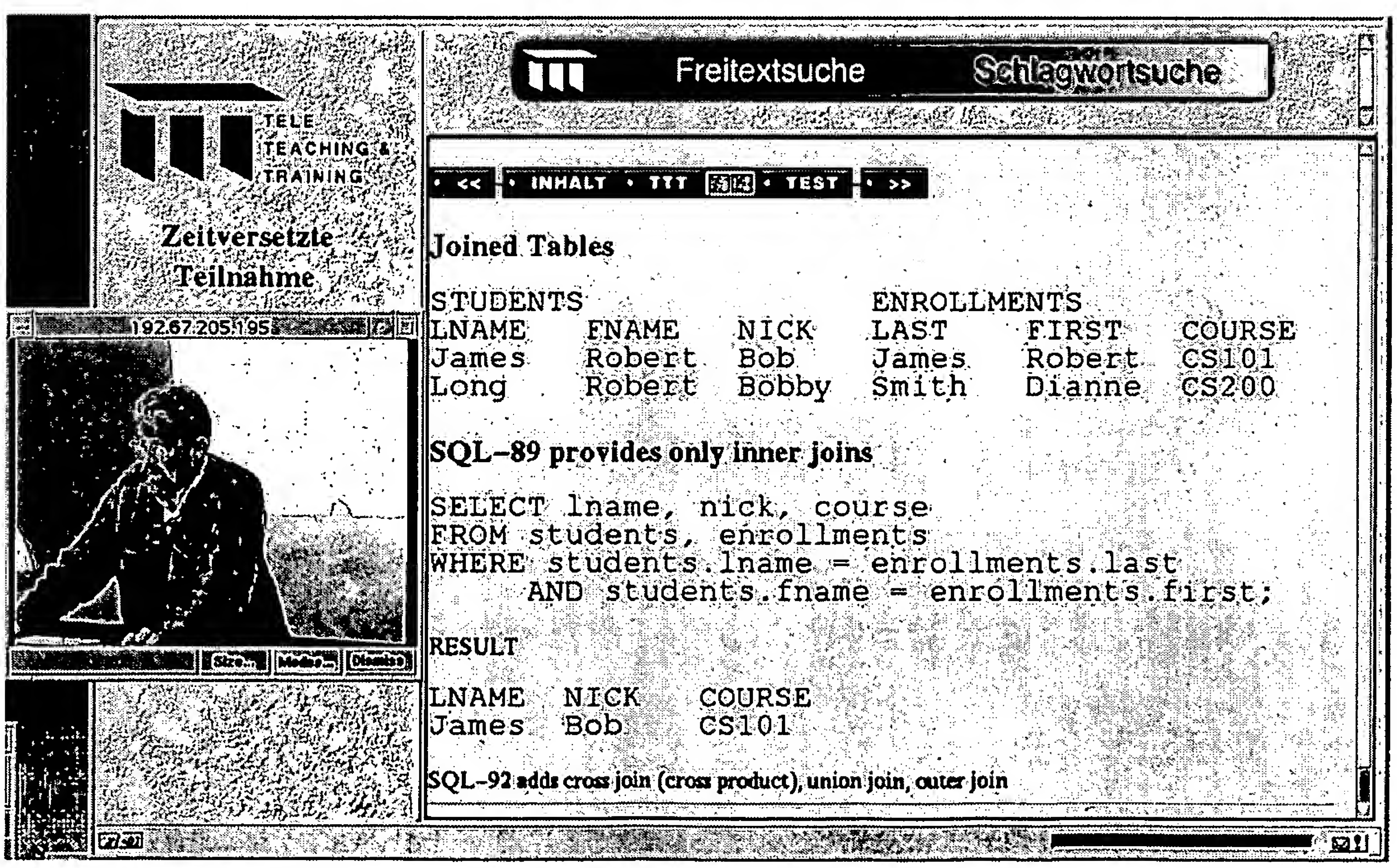

Fig. 21. Integrated presentation: the lecturing video is presented synchronously with the slides used in the lecture.

Professional providers offer more advanced material by relying on additional technologies such as Java, ActiveX and plug-ins. These technologies allow for richer user interfaces with more relevant interaction techniques and, thus, make better use of the specific advantages of the medium. As described above, plug-ins for some authoring systems exist. Courseware created with these systems can then be viewed via the WWW, if the plug-in is installed on the client computer. But plug-ins also encourage authors to deliver courses as single black boxes instead of using the modular hyper-structure inherent to the Web.

HTML-Forms and CGI-scripts can be used to test users and store the test results on the server, thus providing a means to assess user performance. The data collected can be used to evaluate the learning efficiency of the course.

Such WWW courses satisfy only parts of the requirements introduced in previous sections (see especially 3.3, Course Design): HTML does not separate course content and structure, hierarchies of courseware are not supported, and management of even medium-sized Web-sites is still an issue.

Probably the most important drawback of pure WWW courses is the Web's one-shot-approach: a Web-server answers each request separately and does not build up a continuous dialogue with a user. Thus, adaptation to user preferences or user performance becomes practically impossible.

The next section, therefore, describes the architecture of a system to overcome the shortages of the Web by adding additional components to the server runtime and using a Multi-Media Database (MMDB).

The Modular Training System (MTS)

This section describes the architecture of a modular training system based on a generalization of the architectures developed in the IDEALS (see Ref [60]) and COBRA-STI (see Refs [61, 62]) projects (see Appendix C: COBRA STI and IDEALS). The overall concept is to use standard IT technologies for clients and networking and to realize learning specific functions primarily on the server side.

The client is running as course front-end on the user's side, and its main purpose is to download and display the different kinds of basic material used for a course. This is exactly the functionality offered by standard WWW browsers. Therefore, an off-the-shelf WWW browser (Netscape Navigator or Microsoft Internet Explorer) is used as the client.

The enhancement of WWW by specific learning services is done through the connection of a specific Training server, called the MTS Server, to the standard WWW server (see also Refs [51, 59]). Such a server is fundamental for all advanced WWW training concepts. Its design is the key issue for delivering adaptive courses and managing large courseware domains.

The MTS server can be used to include several services necessary to realize the concepts described in Section 3. With respect to individual learning scenarios, the following features are especially important:

Adaptation of the course flow to users' profiles

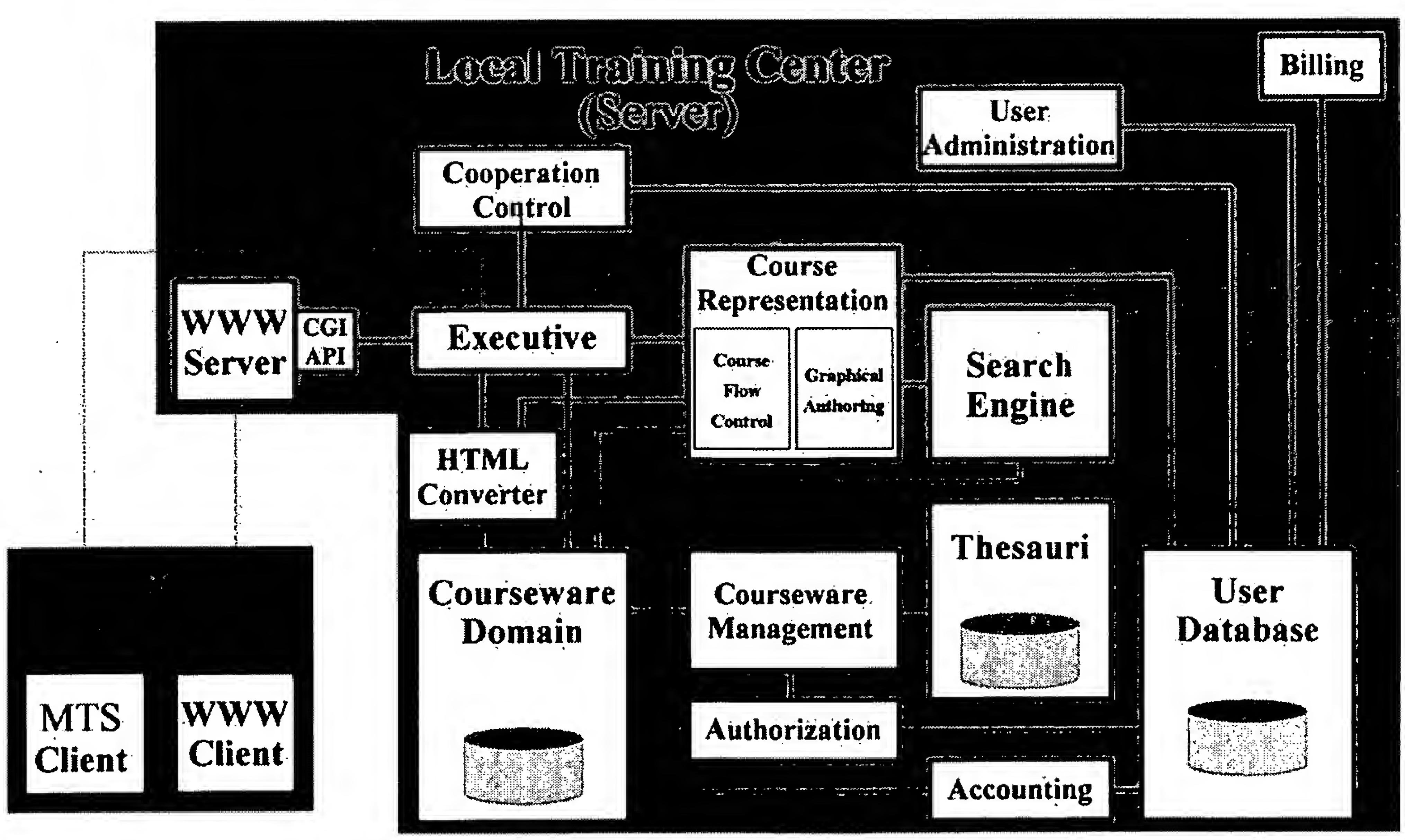

Fig. 22. An architecture for IT-based lifelong learning systems derived from a functional description of the IDEALS MTS server.

search engines for seamless access to distributed material

conversion of HTML extensions, separating content from structure to HTML

courseware management.

All these services are accessed from the Client via HTTP and the WWW server (that is, the WWW Client sends a special request to the WWW server). The WWW server recognizes that this it is a special courseware request and passes it on to the MTS server, using the CGI Interface. The MTS Server will then process the request and send the result back the same way.

The Authoring scenarios add additional modules to the server. These are described in Sections 4.7.4 and 4.7.5. Figure 22 shows in detail the functional components of the MTS server realization used in the IDEALS project.

For Individual Learning, the following modules are relevant:

Executive

The Executive is the central component of the ITBT server. It is connected to the WWW server via a CGI program and acts as the main daemon process coordinating all incoming requests and distributing them to the responsible components or component instances.

Together with the CGI program it provides WWW-specific mechanisms to transparently distinguish the requests from different learners and, thus, allows handling multiple learners and learning groups simultaneously.

The Executive is also connected to the MTS Client via a separate network connection enabling real-time updates of the MTS Client and free usage of external applications related to the course and tools for communication within learning groups.

Course Representation (CR)

Whenever a new course session is started, the executive will create a new instance of the CR, which will be responsible for managing the internal status of this session on the server side. Therefore, the CR holds all the learning-specific session information, such as user name.

Users can run a course either in run mode or, if they have the permissions, also in authoring mode. They can switch between these modes. Because session control for run-mode differs significantly from session control for authoring mode, there are specialized modules for each mode, which implement the specific session controls for the respective modes. The CR delegates the handling of the session control to these modules.

Course Control is based on exchanging messages. Therefore, the CR keeps track of which of the two, mutually-exclusive modules (CFC for run-mode and GA for authoring mode) is currently in charge of the session and passes the messages it receives to this module. Also, the CR handles switching control between CFC and GA, and it provides access functionality to other modules, which is used by both CFC and GA. This includes accessing material in Courseware Management and access to the Search Engine and to the User Database.

So, the CR can be seen as an encapsulation of the CFC and GA, providing a generic interface for session control.

Course Flow Control (CFC)

This module does the session control during run mode. Its main functionality is to handle the course-flow-control-related messages received from the CR. These messages trigger actions of the CFC, which result in a change of status of the session.

How the CFC reacts to such messages is specified by the author. Therefore, the CFC retrieves from Courseware Management (if necessary with assistance from the Search Engine) the course scripts (a course node script) and creates from it an internal representation of the course structure. Based on this internal representation of the course, the CFC can determine course flow.

These node scripts can refer to other node scripts or unit scripts (see also Section 3.3.2, Separation of Content and Structure).

Although Unit scripts are not executed on the server side, the CFC still has to interact with the units. It will provide such functionality as access to the user profile and other run-time information. The unit accesses this functionality by sending special messages.

The CFC is the only module that keeps and maintains an internal representation of the course. To be able to edit the courses, the GA needs access to this internal structure, so the CFC also provides an interface that allows this.

Search Engine

This module handles the resolving of Virtual References to Direct References (see Section 3.3.3, Self-containment of courseware). In a Virtual Reference, the author has given an abstract specification of the required courseware (its subject, contents, and capabilities). For every available piece of courseware, the Courseware Domain contains a description of the subject, contents, and capabilities of this specific piece of courseware. It is now the task of the Search Engine to find out which piece of courseware is the best choice for this specific Virtual Reference. The decision regarding which is the best selection must also take into account the user. Therefore, the Search Engine uses information from the User Database to adapt the selection to the specific user, such as his/her preferences, course history, and learning success. The Search Engine transforms the Virtual Reference and the relevant

information from the user profile into a data base request and issues this request to the Courseware Domain. The result of this request is a list of the best candidates. For each of these candidates, a measure is computed, indicating to what degree this one will match.

One of the central ideas behind world-wide training provision is the creation of a huge, global domain of common courseware. Because the Search Engine makes it possible for a human to handle such an huge amount of available courseware, it is one of most essential components of the system.

HTML Converter

The HTML Converter transforms units (see Section 3.3.2, Separation of Content and Structure) to HTML documents. It retrieves directly-referenced Units from the Courseware Domain, parses them, and replaces direct references by HTML references. Virtual references in the Units are passed to the CR, which uses the Search Engine to resolve them and which returns a direct reference. The resulting standard HTML documents can then be passed to the WWW Client.

4.8.2. *Tutoring and Group Environments.* Tutor workplaces are largely the same as trainees' workplaces as far as hardware and software equipment is concerned—see Table 10. Tutors have extensive access rights to information stored at the server side including information about current sessions such as the members of an active learning group. This information can be displayed by the WWW browser itself.

Tutoring services can be provided by applying a suitable combination of the cooperation services described in Section 4.5. For low bandwidth connections, text based tutoring using email, news groups or chat is the only possibility. But for higher bandwidth connections (EURO-ISDN or better), a much better service can be provided. The combination of audio/video-conferencing with screen sharing allows a student to ask questions just when a problem arises and to demonstrate the problem to the tutor interactively.

For group learning scenarios, different technical realization should be offered in parallel:

asynchronous group learning for trainees with low bandwidth connections. In this case, each trainee uses his/her own instance of the courseware and learns individually. In addition to using the courseware, the group members participate in news group-discussions and exchange emails on topics of interest. This group learning style is often found in today's pure WWW training environments.

fully synchronous group learning. In this case, the group members schedule specific learning times when all of them enter a conference. They use audio-/video-conferencing to communicate and share a single instance of a course by using application sharing. This requires higher bandwidth connections. This scenario can be supported completely by standard cooperation services. However, it requires the group to agree on a common time and pace for learning and is therefore suitable only for homogenous groups.

loosely coupled group learning. In this case, group members learn with their own instance of each course, but they meet each other at synchronization points built into the course for group interaction. This scenario provides more freedom concerning the learning pace than fully synchronous group learning, and it allows each group member to use his/her own user profile for learning. Thus, the advantages of individual user adaptability are available. Nonetheless, the members meet at synchronization points and exchange their opinions. This scenario requires a special group learning module to be built into the course runtime system, because the synchronization has to be coordinated with course flow. It is not sufficient just to add standard cooperation services to an environment developed for individual learning. A close coupling between the course runtime and the group module is needed.

The first two realization concepts make use of standard Internet and cooperation services only and can therefore be implemented directly once the cooperation services are available. It is strongly recommended to implement the extra functionality needed for loosely coupled group learning also, because this realization concepts preserves most of the specifics of IT-based learning while allowing for high quality group interaction.

4.8.3. *Lecturing Environments.* The lecturing scenarios previously described (see Section 3.2.3, Lecturing Scenario) extend traditional lecturing activities in that they allow for time-shifted participation in lectures.

These extensions have to be supported technically by an integrated solution. At the Technical University of Darmstadt, Germany, such an infrastructure (see Fig. 23) has been installed and used with various lectures in the project, Tele-Teaching and -Training [63] (see Appendix C: TTT). The campus of the Technical University is distributed across different locations. In particular, there are university buildings in the center of town and also outside of town. Thus, to attend classes, students often had to change their location in a very short period of time. This situation created the need to support place- or time-independent study. The overall situation is typical for a distributed campus. Therefore, it is expected that the concepts and results of the TTT project can be applied to distrib-

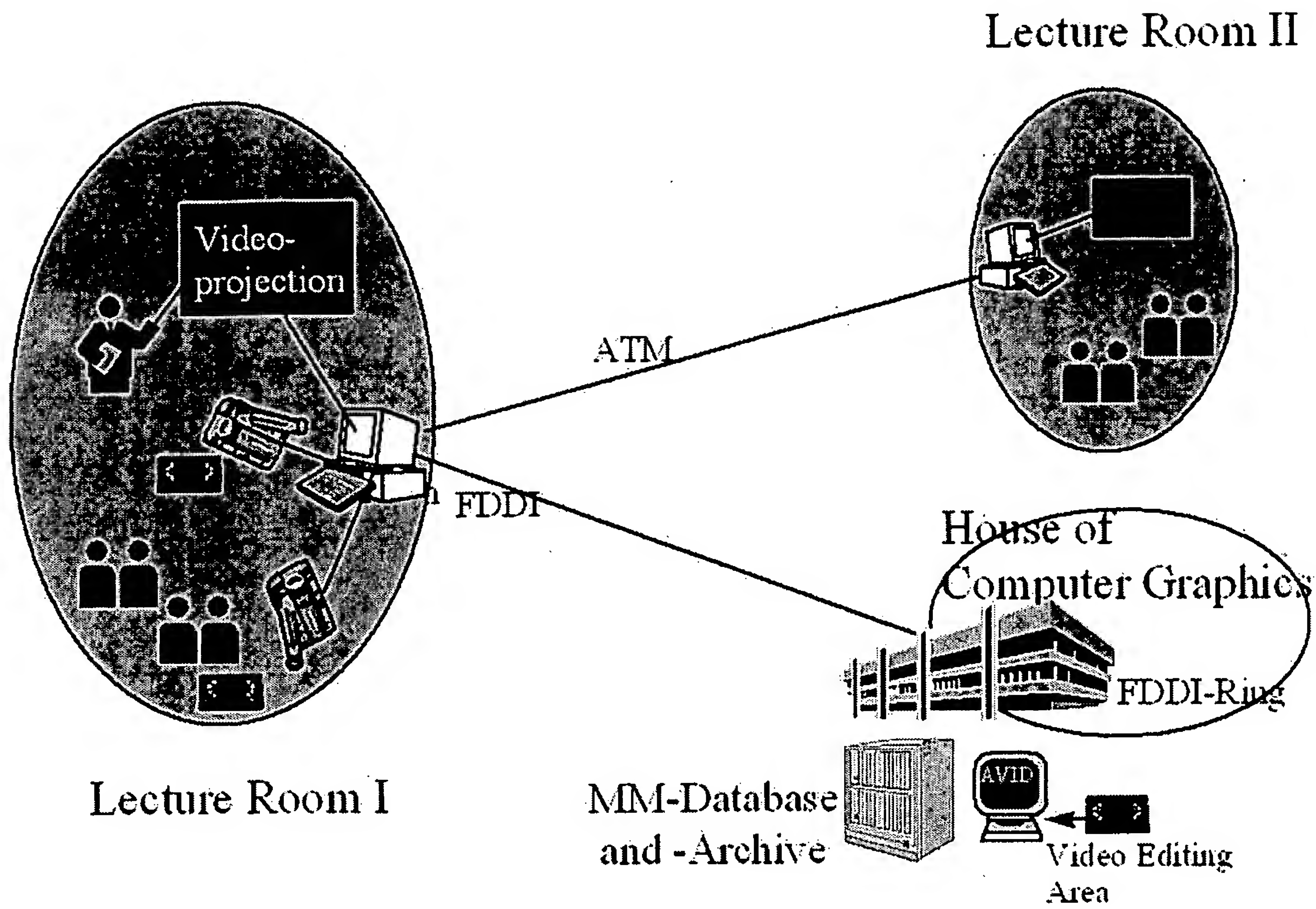

Fig. 23. Equipment used at the house of computer graphics in Darmstadt to connect two lecture rooms for remote participation and recording.

uted training in general. The following description is based on TTT concepts and experiences.

For remote participation in on-line lectures, the lecturing rooms have to be equipped with real-time media transmission technology. Each lecture room should have:

a multimedia workstation for interactive presentations and network control.

a data projection system to display electronic slides and interactive courseware both locally and at remote locations.

video cameras connected to the network to capture a lecture and transmit it to remote lecture rooms.

audio equipment to transmit and receive the lecturer's voice and discussions with participants.

The lecture room should be connected by a high-speed network. The networking infrastructure should hide its lower levels from the applications as much as possible to allow for heterogeneous networks. Using the approach described above, the remote participants can follow the presentation on-line. Because slides are transmitted electronically, they are displayed with the same quality at each location. The video camera usually focuses on the lecturer. During discussions, video images of participants asking questions can also be transmitted.

For audio and video transmission, standard video conferencing data formats should be used. Thus, the presentation can be transmitted not only to remote lecturing rooms, but also to the trainees' workplaces.

In the TTT project, a UNIX workstation (SUN 20/Solaris) was installed in each lecture room, connected to the ATM network of the Technical University and equipped with the ShowMe [64] video conferencing tool. Network transmission rates were up to 155 Mbits/second. Furthermore the lecture room was equipped with two SONY-3CCD digital video cameras and audio equipment to record high quality video and audio streams. For data projection, a high quality overhead panel was used.

In Fig. 24, the hardware and network infrastructure for video and multimedia data storage and editing is shown.

4.9. *Administration environments*

The term administration refers to different tasks (see Section 3.5). Some, like installation and system administration, have to be performed locally at the computing center with full access to the servers. These administrators maintain the system and configure the servers. They are also responsible for managing the connections between sites (cross server-site administration). For example, if server sites exchange courseware, they are responsible for regular database replication.

But many administration tasks can be handled from standard workplaces as they are described

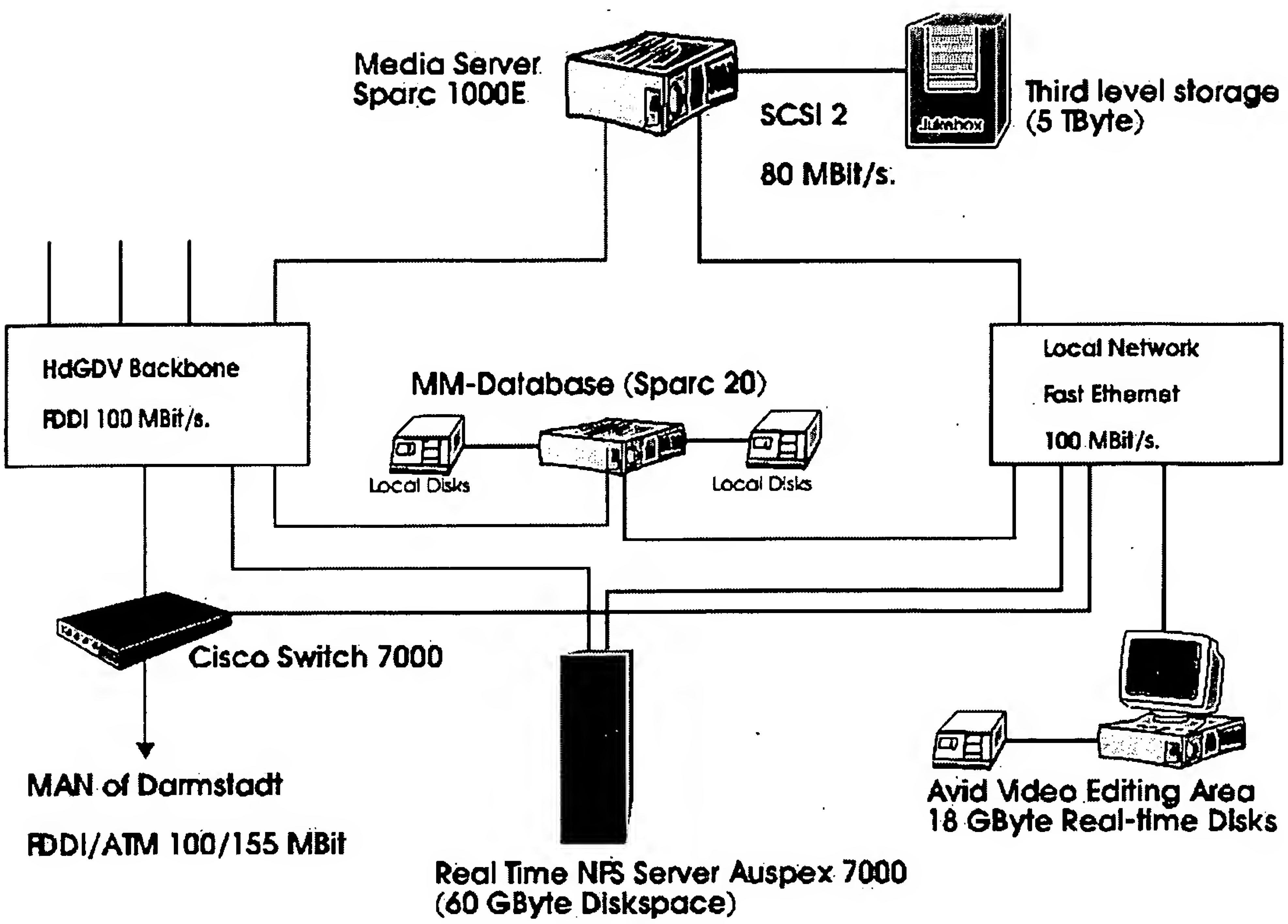

Fig. 24. Hardware and network infrastructure for video and multimedia data material.

above. Learner and author administration, as well as quality control tools, can be implemented as downloadable components. Therefore, those administrators work at a standard author or trainee workplace.

Administration has to be supported by the server runtime. Therefore, several modules have to be added to the training server. They are described in the following paragraphs.

User Administration

The User Administration Module is an independent module that provides all services related to the maintenance of user records in the User Database, e.g., user registration and user enabling and disabling. The User Administration Module provides its own user interface. It accesses the User Database Module which encapsulates the user database and provides the services that require access (with or without modification) of user data stored in the user database itself.

The services of this module are provided to the following modules: User Administration, Authorization Module, Cooperation Control, Course Runtime Module, Accounting Module, and Billing Module.

Courseware Management

Courseware Management is the module that provides general access services to Learning Material stored in the Material Database. The system modules serviced are the Course Representation Module, the Executive Module, and the Converter Module.

The services provided are:

- Load, store, modify, and delete Learning Material. These operations are based on Direct References to Learning Material.
- Retrieval of information on Learning Material. These operations are based on Direct References and aim at retrieving from the Learning Material Database data such as Learning Material Characterization, media type, Production state, and Access restrictions to Learning Material.
- Search. These operations are aimed at finding, in the distributed Learning Material Database, the n Learning Material modules that fit a Virtual Reference best, with n usually being 1 during course delivery and greater than 1 during authoring of courseware.

Authorization

The Authorization Module is the module that is responsible for confirming whether a user is allowed to perform access operations on any piece of courseware material given the user name and the production state of the piece of courseware material and its access restrictions. This check is done against the relevant user record data that the Authorization Module retrieves from the User Database upon user login.

4.10. *Implementation goals and assessment criteria*

The previous sections presented examples of technical implementations as they are manifested within different systems and projects. As is done within these projects, any concrete implementation of the proposed IT-based lifelong learning system has to attend to the quality of the implementation. The quality of implementation is as crucial for success as the design of the underlying concepts and the system architecture.

Therefore, evaluation criteria are outlined in this section. Applying these criteria will lead to an implementation that is appropriate for all distribution scenarios addressed by the business model. For different distribution scenarios, the key factors for successful implementation vary:

for local usage of the facilities at server sites, the focus is on ensuring long-term usability of the infrastructure because of the comparatively high initial investments.

for distributing courseware and services to industry, ensuring return on investment is essential.

broad market acceptance of the technologies used is needed for successful distribution to regional and world-wide markets.

Any implementation must take all three goals into account. Furthermore, all parts of an implementation should posses the following properties:

Well-structuredness

An implementation should consist of clearly identifiable components with clearly defined interfaces. This will allow for 'divide and conquer' approaches when dealing with the system or when changing it. Specifically, parts of a well-structured system can go operational before completing the installation of the full system. Thus, the server site's bootstrapping phase is supported. Additionally, a well-structured implementation will be more open, extensible, sustainable, and maintainable.

Sustainable

An architecture based on today's technologies have to compete against upcoming future designs. It is, therefore, important to plan for long-term usage right from the start. Conformance to both formal (*de jure*) standards and informal (*de facto*) standards is a key issue here. One should check whether guidelines of the following kinds can be applied suitably for parts of the system:

- standards published by internationally important standardization organizations such as the ITU, ISO and ANSI.
- guidelines published by industrial consortia such as the Object Management Group (OMG).
- *de facto*-standards set by companies with dominating market penetration.
- results and evaluations of projects related to the field, such as DEDICATED, CTA, TTT, IDEALS, or COBRA-3-STI (see Appendix C).

It is currently impossible to predict the possible changes in the basic architectures and operating systems for personal workplaces and servers. The dominating role of today's Personal Computers might or might not be challenged by the new generation of Network Computers (NCs) and Java Stations. Windows NT will presumably play a more important role in the server-OS market, but it is unclear how this will affect the market shares of UNIX, OS/2 and the new Novell Netware. As a general observation, diversity can be considered to be the clearest trend in these markets. SoHos (Small Offices/ Home Offices) are likely to use different approaches than large companies that need to manage numerous systems. Mobile Computing might use yet another technology and so on. It is, therefore, necessary to define an architecture that is not tied to a specific basic technology. Heterogeneous environments have to be supported. Details of the low level implementations should be hidden from the applications as much as possible. Different parts of the system should be connected through high level interfaces to allow for realizing the components on top of different basic technologies.

Open

An implementation should support inter-connectivity and interoperability with other standard platforms (see also Refs [65, 66]).

Reliable and Robust

The implementation needs to be checked for reliability. The system's minimal performance has to be on an acceptable level. Robustness addresses the system's ability to cope with unexpectedly internal or external conditions. This usually implies the introduction of redundant elements such as backup servers.

Scaleable

Scaleability refers to two characteristics of an architecture:

the infrastructure has to cope with increasing numbers of users and an increasing amount of data to be handled.

the software has to be adaptable to different amounts of available resources, e.g., home users will have less bandwidth available than on-site learners.

Maintainable

The functionality for keeping the system operational and removing erroneous conditions has to provided in an adequate way.

Performance

The system's average performance needs to conform to the users' expectations and requirements implied by multimedia courseware. Users' perception of courseware quality can be reduced significantly if the system's performance is poor.

Affordable

The cost of installation of learner workplaces and complete server sites needs to be in an acceptable relationship to the perceived return on investment to ensure market acceptance.

More detailed information concerning criteria to describe and analyze training systems can be found in the Common Training Architecture (CTA) handbook series [67]. CTA has been set up by a consortium of research institutions, training providers, and enterprises in a project sponsored by the European Union (DELTA project 2023). Work was directed at the harmonization of technologies, systems, and infrastructures, and their adaptation to flexible international distance training services. These objectives imply also a long-term view of the requirements of key players and the identification of meta-models and reference architectures (see Appendix C: CTA).

A detailed discussion of technical options concerning the Common Information Space would be much too lengthy for this document. It can be found in the Common Information Space (CIS) handbook of the CTA handbook series. One of the main results is the following:

be user friendly. It is recommended that one applies design procedures known from user-centered design and to use the Open Communication Interface (OCI) handbook of the CTA handbook series as a guideline.

Another important issue is the learning environment's ability to adapt itself to different technical conditions: a learner might have different bandwidths available dependent on his or her location (at the server site or at a company with remote access to the server site or at home with a modem connection). In order to provide the learner with an attractive learning environment in all these cases, the learning environment should:

make use of a high performance network connection, if it is available.

be able to integrate data stored on CD-ROMs (so-called Web-CDs) or other off-line storage media. Then, a low bandwidth connection to a server can be used to transfer only updates and uploads such as user profiling data.

be able to work off-line after downloading a sequence of learning objects.

4.11. *Conclusion*

In this section, the different aspects of technical implementation have been studied. For each topic, there are solutions that are either commercially available or have been proven in research projects. Nonetheless, there is no ready-made solution that covers all aspects. Any concrete implementation will consist of a variety of off-the-shelf products and special developments. In Section 4.7, the most relevant criteria for assessing such an implementation approach have been described.

This sections's content concentrates on the presentation of technology already available. Because of the constantly growing market for educational technology, more and more major IT enterprises extend their developments in this area. It is, therefore, important to study the market continuously and to take the latest developments into account. For example, Lotus announced a plan to release Web Access to Learning Space for the first quarter of 1997. Oracle announced the so-called 'Oracle Learning Objects]—Architecture for the summer of 1997. If the announced features are available, these would be interesting systems for certain delivery scenarios. The IDEALS project's demonstration phase also begins in the summer of 1997. It will provide more practical experience with truly international cooperation in courseware production, delivery, and reuse. This might lead to certain refinements concerning technical needs for world-wide distribution. It will also provide more insight into requirements for efficient maintenance of distributed server sites.

The implementation technologies suggested in previous sections differ in their degree of maturity. Some tools have been available on the market for several years now. Their reliability and usability has been improved over time. Other components are relatively new and have been tested with certain user groups or within certain cultural settings only. The integration of technologies necessary to support all aspects described for both local and world-wide delivery at university and industrial sites has to be performed with extra care. There is still comparatively limited experience available concerning the realization of advanced usage scenarios (such as cooperative learning) for user groups distributed world-wide.

It is beyond the scope of this paper to provide a detailed risk analysis of implementation issues, since this is largely dependent on the concrete implementation to be chosen. Nonetheless, further risk analysis is important to ensure return on investment. In parallel with the definition of concrete project proposals, major risk factors can be identified and clarified in more detail. This may include rapid prototyping techniques, small scale pilot tests or stress tests in demonstration centers dedicated to testing large scale usage. The issues identified can then be given special focus. All project proposals should be

questioned with respect to the risk factors. If necessary, enhancements should be negotiated based on the prototype results achieved in the risk analysis process.

Based on experience from the projects described in Appendix C, and general knowledge about turning prototype results into large scale applications, the following areas can be foreseen to need special attention. These areas can be distinguished as different views to the whole scenario:

View of the learners

Corresponding to the large variety of users, a whole spectrum of consistent learning scenarios has to be taken into account, ranging from stand-alone learning at home to tutored group learning in computer labs and from individual, on-demand information retrieval at home to life participation in computer-supported lectures in universities.

Courseware efficiency must always be taken into account and has to cover all cost and benefit factors with respect to the learners. Judgments concerning the quality of courseware and user interfaces underlie these efficiency demands.

Group Learning is currently realized mostly through standard CSCW tools. It needs to be insured that these tools are sufficiently linked to the courseware itself. User acceptance cannot be taken for granted if the semantic connection between courseware usage and group activities is not strong enough. The actual work flows for tutoring and asynchronous group work have to be studied carefully. Otherwise, relevant features such as scheduling and queuing learners' requests are too often neglected.

View of the authors and courseware producers

The central idea for authoring and production must be that of production avoidance. Provisions for keeping existing courseware visible to the authors and for making it re-useable (ready for modification), both from the courseware concepts and from clear rules concerning intellectual property rights, must have a very high priority. Provisions must be taken so that authors can rely on a long lifetime of their courseware in the system concerning software and equipment.

It must be seen clearly that authoring of courseware does not only require topical knowledge but also pedagogic, didactic and technical expertise. Typically, a single person does not cover all of this. This implies the support of integrated teamwork and appropriate interfaces for the different members of such teams.

View of the teachers and trainers

Interoperability of special equipment for lecture support on the basis of the existing infrastructure of the universities is only a minor topic compared with major changes. The prospective new role of teachers and trainers in becoming builders of courses from existing courseware has to be considered. This includes not only the provision of appropriate user interfaces to the learning and training environment but also a mental change for a large group of persons. The advantages of a new-generation system (such as having a large variety of excellent learning material at hand and of getting objective feedback concerning the progress of the learners) must become very clear to the teachers and trainers.

View of the administrators and ITBT service suppliers

Here, technological aspects concerning delivery are more important than in training sites, as they affect marketing conditions. Even for local usage, the integration of different distribution channels such as CD-ROM, WWW and real-time-transmission can enhance usability considerably.

Administration of distributed courseware domains is a complex task. It involves providing mechanisms for quality control, release management, sharing access rights between cooperating authors, and accounting and billing between remote sites. Handling of intellectual property rights for courseware access is very important for effective business operations. The selection or design of tools to support these issues is therefore a major topic to be addressed. Although standard databases provide a means for most of these tasks, combining these mechanisms with WWW-access to the database and database distribution will not be straightforward and might require additional developments.

Certification of the learners' activities and the provision of certification transfers are a must. This requires substantial changes in the regulations of teaching and training institutions, which, to date, typically rely on personal qualities of their selected staff. Matters of data security affect the learners substantially as soon as these are monitored in order to get their profiles and to be able to certify their progress.

View of the system designers

Performance requirements of growing user communities do not grow linearly. A typical scaling error is to project results from small scale projects to large scale applications directly. Details concerning parallelization, distribution, and replication are likely to be neglected at first, if they are not addressed explicitly.

Because of different data formats used by these media, their integration requires adequate design for cross-media publishing from the beginning. Software and equipment underlie continuous changes. The observation of and the openness to formal standards and, more than these, industrial standards are a very important means of providing long-living products and must be taken into account.

The list of views above is based on contributions from project partners and commercial courseware providers. It provides an initial overview of issues to be addressed and has to be extended by a more detailed examination of the risk factors.

5. CASE STUDY

5.1. *Summary*

After describing the concepts for IT-Based Lifelong Learning and presenting aspects of the technical implementation, this section demonstrates the application of the proposed concepts and technology for a specific case. As an example, a course curriculum for 'Visualization, Multimedia, Interaction, and Communication' is presented.

This case study has to be seen as a concrete example of all possible curricula that could be taught in a university, which could be delivered either in a conventional manner or using the proposed technology. We assume that 10–15% of the science students will use this IT-based course of study, at least in the bootstrapping phase. The students taking these courses should be used to evaluate, redesign, and optimize the architecture, technologies, and implementation.

In addition, this curriculum should be viewed as a minimum set of courses. In a typical university program, students will have to take a set of required courses and then fill out their program by selecting from an additional set of optional courses. Therefore, a full curriculum will need to offer more than the minimum required set of courses. Furthermore, depending upon the optional courses taken, a student might earn a degree with a specialization; e.g., in virtual environments, in human-computer interfaces, in systems architectures. Decisions in this area will depend upon local policies and strategies for the new universities including their additional role for the industrial parks (e.g., continuing education, training programs).

The roles of a curriculum in the context of this Concept Paper are:

Helping to find requirements and specifications for the concepts and system architectures.

Serving as a testbed for evaluating its functionality and feasibility.

Supporting the promotion of the role of IT for the new universities and industrial parks in Sabah and also, more generally, for the Multimedia Corridor vision in Malaysia.

This section gives an overview of the proposed curriculum and estimates the effort for the creation of the ITBT courseware for this curriculum. Furthermore, the environment for this case study will be described from the technical point of view. A detailed specification of individual courses, however, has to be the subject of future activities.

5.2. *Motivation of the case study*

There are diverse reasons for doing a case study on computer based training:

- Proof of Concept.

  Although the proposed concept for the SW-system and courseware has been demonstrated in various projects, its adaptation to this large scale applicationCintegration into an IT-based program in a modern university—will be aided by this case study.

- Bootstrapping of the educational environment for an IT-based program at the new University in Sabah, Malaysia.
  The case study will demonstrate Computer-Based Training immersed in the local networking environment.

- Bootstrapping of a Training Server for Malaysian Industrial Parks, such as Kota Kinabalu Industrial Park (K.K.I.P.).

Industrial parks in the planned Malaysian Multimedia Super Corridor (MSC) will profit from the ITBT services provided at the new University of Sabah. In addition, the envisioned ITBT activities will support the promotion of Sabah in the context of the Malaysian multimedia corridor.

- Installation of a first set of courses for a possible future 'virtual university'.

  This course will offer a top quality curriculum designed by outstanding international experts.

- Bootstrapping of a local Environment for Courseware Production and Maintenance.

A large industry is expected to grow around courseware production. The case study can serve as a stimulus for a Malaysian Courseware Industry.

- Evaluation.

This will cover evaluating the final outcomes and results in relation to intentions and objectives as well as the implementation process.

The case study will permit one to validate and fine tune the cost estimates and effectiveness of the curriculum development approach. Evaluation as a process is described in more detail later in this section.

5.3. *Suggested contents of the case study*

A complete three-year course in Computer Science with an emphasis on 'Visualization, Multimedia, Interaction, and Communication' is suggested. The program is based on three levels of courses and a thesis and has to be aligned with the

current timetables of UM Sabah with its program of 2.5 semesters per year.

The layout of the curriculum structure has to consider the quality and content of education. We recommend the following three-level structure:

First Level Courses

This level provides an introduction to some of the mathematical, technological, and scientific foundations that will be needed throughout the second and third level courses. The following list gives the first level courses:

A.	Linear Algebra and Basic Geometry
B.	Analysis, Discrete Mathematics and Numerical Computation
C.	Computer Systems
D.	Computer Networks, Internet, WWW
E.	Object-Oriented Design and Programming/ Algorithms/Data Structures
F.	Visual Communication
G.	Computer Graphics I (Basics)

Second Level Courses

This level reinforces the foundations; the focus of the second level courses is the study of multimedia and visualization support technologies. The following list gives the second level courses:

A.	Probability, Random Variables and Stochastic Processes
B.	Network Protocols and APIs
C.	Software Engineering
D.	Visual Computing
E.	Operating Systems
F.	Multimedia Systems
G.	Interaction and User Interfaces
H.	Coding Techniques and Data Compression
I.	Computer Graphics II (Geometric Modeling + Rendering)

Third Level Courses

This level studies the state of the art in visualization, multimedia, and interaction development technologies. The program consists of mandatory and optional courses. The following list gives the third level courses:

A.	Computer Vision
B.	Audio and Speech Processing, Recognition and Synthesis
C.	Computer Animation
D.	Virtual Environments
E.	Scientific Visualization
F.	Advanced Geometric modeling
G.	Video
H.	Data Security, Cryptography
I.	Broadband Communication Systems
J.	High-performance Computing Systems

When the three levels are completed by a student, a thesis in the form of a project or a case study in one advanced topic is planned to finalize the course curriculum about 'Visualization, Multimedia, Interaction, and Communication'.

Based on the requirements, architecture, and implementation approach proposed in previous sections, an international team of experts should support the local experts in:

- detailing the content and structure of the curriculum,
- identifying sources of the content and possible content providers,
- weighing the importance of and assigning resources to each course,
- estimating the different types and quality of MM for each course,
- specifying the learning scenarios associated with the delivery of the content,
- sketching promotion, marketing and licensing scenarios together with publishing companies.

It is essential that this team consists of international experts from major universities in Asia, Europe, and North America. Together with local experts, they should flesh out the envisioned scenario.

5.4. *Estimated extent and cost of the case study*

The amount of courseware required for this computer-based course is calculated using figures for a typical European university:

One year of studying means a minimum of 1500 h of learning. This corresponds to the average number of work-days accounted for in 1 year and takes into account vacation, holidays, and sick days. In order to simplify the calculation process at this time, we assume that traditional learning and

ITBT are equally efficient. However, in reality it is foreseeable that ITBT learning will be somewhat more efficient due to the exploratory nature of this method:

Minimal yearly learning hours for a student: 1500 h

On average, 50% of the learning time is expected to be computer-based learning; the remaining 50% is expected to be devoted to reading (scripts, books, Web, etc.), discussions (with other students, tutors, scientists, professors, etc.), and practical work (like seminars, projects, diploma thesis):

Expected percentage of ITBT usage for learning: 50%

Thus, 750 h of computer-based learning will be distributed over about 195 days. This means a bit less than 4 h of ITBT learning a day on average—a number that seems to be reasonable. It is assumed that exercises and examinations are integrated into this ITBT-based learning:

Expected computer-based learning per day: 3.85 h

For a three-year, full-time course, 3×750 h = 2250 h of ITBT material are required as a minimum. Due to individual adaptation, on average, every student is expected to use about 75% of the total available courseware. This translates to a minimum of 3000 h of courseware required.

Minimal amount of courseware for a three-year course: 3000 h

It is agreed among experts that there is a production-time/session-time ratio (the production factor) ranging from 100 up to 400 (see Refs [21, 22]). Depending on the quality of those courses (especially their use of interaction), the production factor is lower or higher. These courses do not provide means for profiling and individual adaptation. For the next generation courseware, a certain percentage of interactive simulated micro-worlds will be a requirement for being considered as having acceptable quality. Therefore, the initial effort for courseware production will even grow while stepping forward to the next generation while the ease of multiple use and re-use will grow substantially with the higher awareness of courseware producers of courseware modularity. In our estimation, a minimal production factor of 300 is assumed for the production within this case study.

Expected minimal ratio production-time/session-time: 300

Based on the above estimates, a three-year course represents a production time of about 900 000 h. This amount of hours represents 600 man-years (at 1500 h/man-year).

Expected personnel cost for a three-year course: 600 man-years

This number of hours is a mix of personnel hours in a team of people with different expertise and personnel cost. The time might be reduced in cases where a certain amount of the work can be assumed as having been done already due to state-of-the-art lecturing activities. In Table 11, the required amount of time is distributed over the kinds of people involved. The suggested portions reflect how time-consuming the different kinds of work are. Because we expect that some work has already been done, the total amount of time for different kinds of people is reduced. In the end, this leads to the total estimate of less than 600 person-years.

The calculations and the figures in Table 11 have to be seen as a first order estimate: they give us a good sense of the effort necessary for the courseware creation. In addition, the table illustrates that the transition from almost no ITBT courseware to 100% highly interactive courseware cannot be seen as a single step but rather than as a process with various steps and in-between results. An example of

Table 11. Calculation of labor required (in person-years)

	Time required (total)	Professional level	Percentage possibly done	Percentage still to be done	resulting person-years
ITBT Management	15%	Supervising professor or manager	0%	15%	90
Didactic Structure	10%	High-Level scientist (e.g., professor)	5%	5%	30
Design and Layout	10%	Junior researcher, layout specialists	0%	10%	60
Coding and Media	25%	Technician, multimedia experts	10%	15%	90%
Simulated Micro-worlds Production	30%	Junior researcher and programmer	0%	10%	60%
Testing	10%	Senior researcher	0%	10%	60%
					resulting person-years for a three year course: 510

an in-between result might be the fast one-to-one translation of traditional (overhead-based) lecturing material to low-level ITBT material.

A second-order estimate of the effort to produce the courseware might use a more elaborate model. The estimation process in the following model takes into consideration the extent of the different extensive media and micro-worlds usage required for a certain course as well as the general concepts introduced in Section 3.

Generally, five different types of multimedia objects can be distinguished:

Text
Sound
Graphics
Video
Micro-world.

Depending upon the effort necessary to produce one time unit (e.g., 1 h), which might be based on empirical data, the types of objects can be weighted with values u_i. In addition, the content and didactic experts estimate the contribution of each object type to their course in advance by using a fraction w_j where $\Sigma\ w_j = 1$. Having these two figures, the average hour h_x of courseware will require $= \Sigma\ u_i w_j$ hours production effort. This value h_x can now be interpreted as a *production cost index* (*pci*) for an individual course x. By multiplying this *pci* with the number of hours an individual course x covers, an estimate of the production costs of one course x can be obtained. Summing up the estimations for all courses gives the costs for the complete implementation of the planned courseware.

It is clear that this second order estimate will not completely match the real world costs, because many variables and cost factors are not yet integrated into the calculation model, but it implements a stricter relationship between costs and the used object types in a course (which in an elementary way reflects the quality of the courses).

5.5. *Equipment cost*

Technically the students can access the ITBT material from either the university labs and/or from at home. However, the proposed scenario should allow all students access from university labs. Assuming that we want to install working places for 3000 students and assuming that 3 students share a learning place, 1000 places have to be installed (e.g., 30 labs with about 34 PCs). Additionally, about 30 interconnected servers will be required for the course operation with these students. Four lecture rooms equipped with multimedia environment and video projection will be needed for conventional fractions of the course and learner guidance.

The above estimates (shown in Table 12) make the following assumptions:

The network and building infrastructure is already in place and not included in the estimates;

The operating costs and maintenance of the hardware and software are not included in the estimates;

Commercial, off-the-shelf software for the learner places and servers are included in the estimates.

Considering the costs for the more than 500 person-year courseware production, it becomes evident that the costs for courseware development are an order of magnitude higher than those for technical investment. This ratio is reduced by the fact that the depreciation time for courseware can be estimated to be more than the five years as is commonly assumed for equipment. Upgrading courseware includes a lot of re-use. Opening the provision of courseware to the 'outside' distributes the costs to substantially more shoulders as soon as high quality and attractive courseware is provided.

Even in the case of a new, IT-based university, it is expected that teaching, training, and learning will be, at least at the beginning, a mix of conventional and computer-based activities. All activities have to be monitored and evaluated in order to estimate efficiency factors and to optimize the mix.

5.6. *Evaluation*

Evaluation is an important activity for any project on teaching and training and nowadays a must for all advanced and innovative projects. It is a hard task to carry out, mostly because of the complexity of the elements under evaluation and its closed relationship. For supporting the evaluation of the results achieved during a project, an

Table 12. Estimated costs for the equipment

	Number	HW/SW Cost/Installation (US$)	Total Cost (US$)
Authoring places	100	6000	600 000
Learner places	1000	3500	3 500 000
Course servers	30	30 000	900 000
Lecture room equipment	4	200 000	800 000
MM servers	10	100,000	1 000 000
Total sum:			6 800 000
Estimated costs for equipment:			US$ 6.8 Million

evaluation strategy has to be developed, in accordance with the possible resources for these purposes and based on specialized information.

First of all, the evaluation objects should be identified and defined, as well as the main stakeholders and actors involved in the evaluation process.

The first evaluation step is the specification of the criteria for evaluating and monitoring the teaching and training project. Special attention is due to the activities related to technology development and integration, courseware generation, learning material adaptation and integration, course configuration, course distribution, and course execution in different learning and demonstration scenarios. Detailed evaluation of the effectiveness and efficiency of the modular training system at all critical stages has to be defined.

Some of the 'guiding principles' usually related to evaluation of learning technology are:

Evaluation involves different *actors*, who have different levels of evaluation experience, varying degrees of familiarity with the domain of learning technologies, and particular methodological preferences.

Evaluation entails different *evaluation needs*, which are shaped by different configurations of events or moments within an innovation life cycle.

Evaluation mirrors the *innovation process* and is not just about formal procedures, such as testing. It is also very much about managing contingency, about addressing conflicting agendas, and about adapting to change.

Evaluation is more successful when it is informed by understanding about the wider social and cultural contexts in which learning technology innovations develop.

When defining an evaluation plan, the following principles have to be considered:

It is concerned with both the progress of innovations and with making judgments, e.g., about success and failure.

It is developmental for the parties involved, with an emphasis on learning and improving.

It recognizes the different parties with a stake in the evaluation and enhances their participation in the evaluation process.

It places emphasis on utilization and dissemination of evaluation information.

It leads to the reappraisal of actions and policies through information and learning.

The evaluation of an IT-Based Lifelong Education and Training project should be concerned with:

The nature of the partnership construction and the influence of lead actors in setting the development trajectory of the innovation (market arrangement, technology constellation).

Relations between the project and strategic actors in its external environment.

Project organization and decision-making structures and processes.

The dynamics of the project and its capability as a dynamic, learning organization.

At the broadest level, learning technology innovation consists of new forms of education and training carried out in educational or economic systems. Defined in this way, a specific telematics application in the education and training domain is usually engaged in four aspects of innovation:

pedagogic, i.e., to improve teaching and learning;

institutional, i.e., to establish new practices in user organizations;

economic, i.e., to create new added-value and/or reduce costs;

technological, i.e., to apply available technologies to actual needs.

In specifying the scope of evaluation, it is important to begin by analyzing the innovation in relation to the four aspects of innovation listed above. The very act of doing so may reveal a hitherto neglected or unrecognized facet of the innovation that needs to be further elaborated or incorporated more overtly into the evaluation plan.

Because the 'object' of evaluation is complex, the scope of the evaluation itself will need to cover both:

- outcomes and results, i.e., evidence as to what has been achieved in relation to intentions and objectives; and
- implementation processes, i.e., a description of the way these results were achieved, including key decisions taken and problems encountered.

It is only by covering both *outcomes* and *processes* within the scope of the evaluation that it is possible to account for, explain, and generalize results of projects to the wider Learning Technology community.

The choice of evaluation methods is shaped by what the evaluation is for, the focus of the evaluation, and the kinds of questions being asked of the users and audiences for the evaluation. It is also shaped by their views about what constitutes valid and reliable data, available resources for evaluation, other logistical considerations, and the expertise and methodological preferences of the evaluator(s).

An evaluation plan is not a once-and-for-all-time activity. Projects will need to prepare an initial plan during the start-up phase and to keep it under periodic review. At key intervals or milestones, it might be appropriate to develop a new plan for the

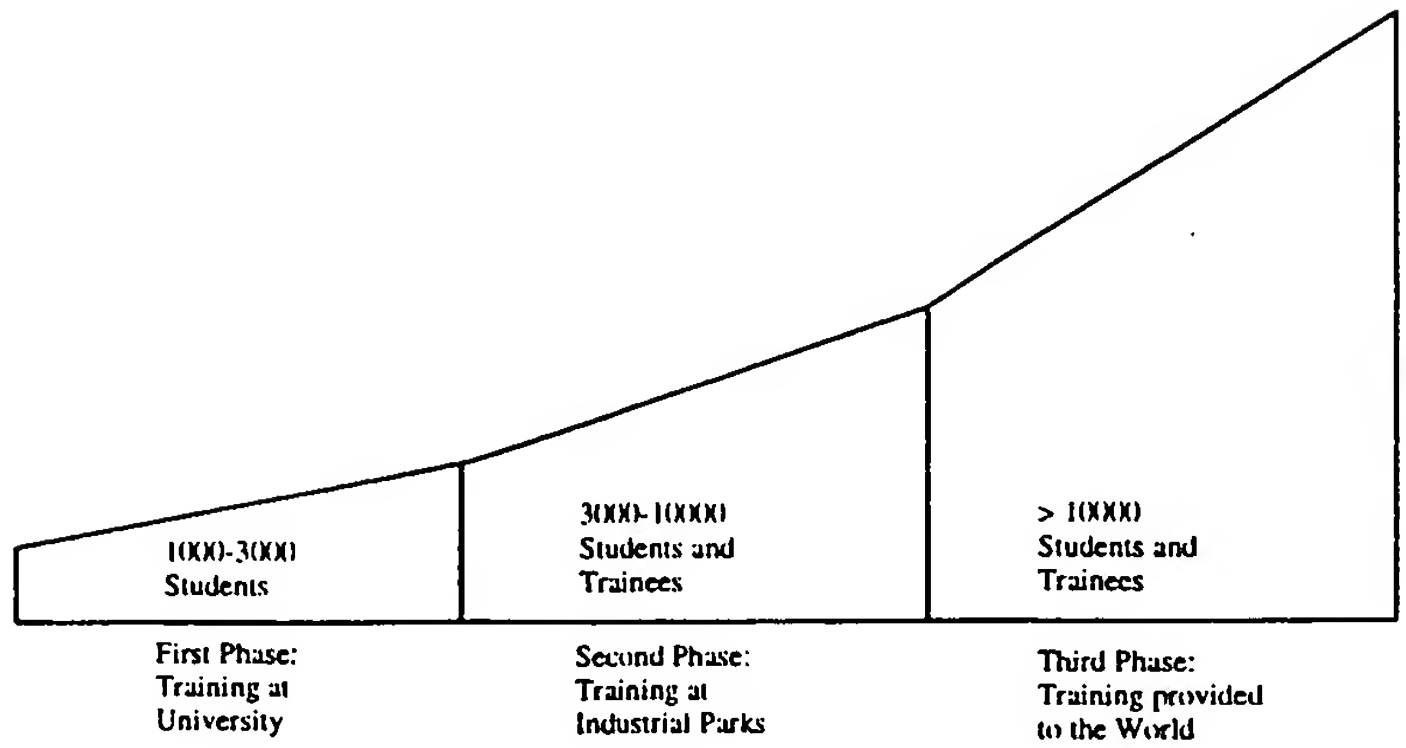

Fig. 25. Number of trainees within the different business model phases

coming phase of the work and to show how the activities will feed into and influence later phases.

To be useful, an evaluation plan needs to be coherent, relevant and feasible. In drawing up a plan one needs to ensure that:

- it 'hangs together' so that the various elements are congruent and reinforcing;
- it addresses the concerns and objectives of the key stakeholders, and it generates data that are credible and useful to them;
- it is well matched to the financial, human, and institutional resources available for the evaluation.

5.7. *Conclusion*

Undertaking the development of a Case Study Curriculum (a set of courses that, taken together in a specific sequence, leads to a academically recognized degree, like Master of Science or Diplomarbeit) would be a crucial part of any effort to implement the concepts and visions expressed in this paper. This, together with a pilot system implementation to test critical hardware and software (see Section 4) and the development of a full business plan (see Section 6), form the three legs on which stands the whole idea of IT-based lifelong learning.

6. WORK PLAN AND COST ESTIMATION

6.1. *Summary*

Based on the concepts defined during the previous sections, there is a need for a Business Plan for IT-Based Lifelong Learning. The Business Plan should include:

- Business Model and Goals
- Work Plan
- Cost Estimates
- Income Sources
- Risk Analysis.

While it is beyond the scope of this Concept Paper to prepare such a Business Plan, we can give some preliminary estimates and ideas based on our experience in IT-Based Learning projects (see Appendix C) and based on the inputs developed at the March 11–13, 1997, Workshop in Sabah.

6.2. *Business model and goals*

This section suggests a business concept for how to establish an IT-Based Lifelong Learning Program at the University in Kota Kinabalu, Sabah. The following list specifies the basic input parameters within this business model:

- initial number of course curricula
- initial number of students at the University
- initial number of trainees at industrial parks
- project duration.

These parameters are scaleable depending on the resources that can be allocated for the project realization.

The main goals addressed by the business plan, which have already been mentioned above, are the following:

- Integrating an IT-based lifelong learning system into an Institute of Higher Education, such as the new university in Kota Kinabalu.
- Providing IT-based training and learning to industrial parks.
- Exporting training and learning access over the Internet to the Southeast Asian region and, finally, to the whole world.

These steps have already been shown in Fig. 2.

Assuming these three goals, which can also be considered as implementation phases, it can be foreseen that the following growth of the number of trainees could take place as shown in Fig. 25 (the word 'trainee' is taken to include students officially enrolled at the University, people from companies in the industrial parks, and individuals reached over the Internet who take ITBT courses from the University).

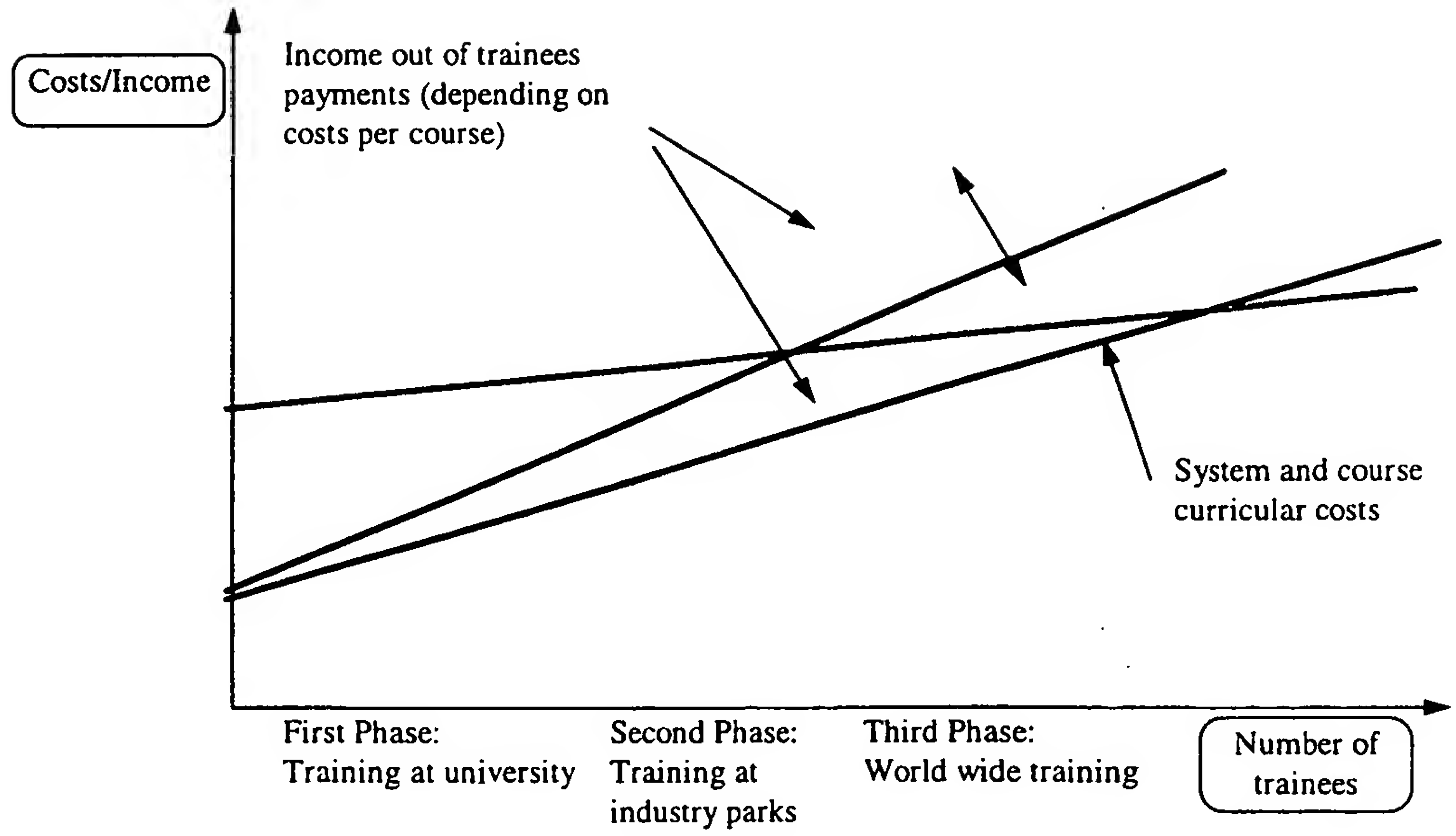

Fig. 26. Costs and income relative to the number of trainees.

If it is assumed that every trainee pays nearly the same amount of money for a course, the income is linear with the number of trainees (the costs per course define the coupling factor). The costs for the system environment and the operating costs for the new university program will be foreseen to start at a relatively high level (high costs for infrastructure establishment and for development of the first curriculum) but then will increase only slowly with the number of trainees. Bringing this together, the following trend diagram (Fig. 26) is foreseen to show costs and incomes in relation to the number of trainees.

The numbers in Fig. 26 assume that nearly the same course content will be delivered to the different groups of trainees. Furthermore, in this diagram, 'income' is used to refer to payments on behalf of the trainee, regardless of whether that is paid for by the individual, a company, or the government.

Another important ratio is shown in Fig. 27, which shows the authoring costs relative to the number of course curricula developed. Within this figure it is assumed that the concept of courseware re-use and courseware multiple-use is implemented as suggested in Section 3.3, Course Design.

At the beginning of the course authoring process when no courseware is available, the costs per curriculum are at a maximum. With an increasing amount of curricula developed, it can be assumed that more and more courseware modules will be reused. But, because the courseware retrieval success will be very low at the beginning, it will take a while until reuse will show a significant effect on the

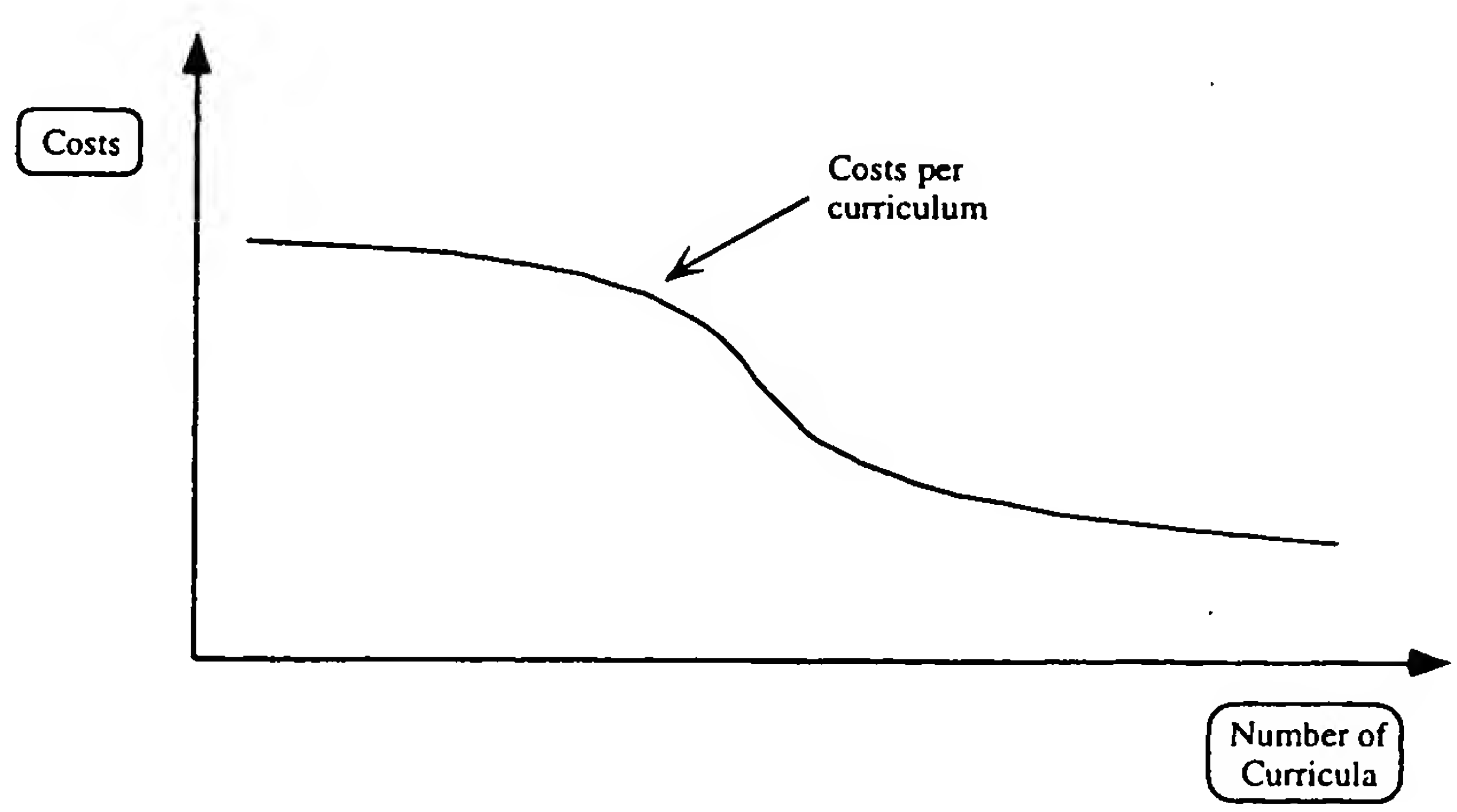

Fig. 27. Costs relative to the number of curricula.

Table 13. Project milestones

M1:	Start of system development and course authoring
M2:	Detailed specification of software and courseware
M3:	System prototype is ready, and test course material is available
M4:	Pilot system is ready, 1st stage of courseware is available. Start of ITBT-based lecturing
M5:	2nd stage of courseware is available
M6:	Complete system is ready
M7:	3rd stage of courseware is available

bottom line. The nearly constant minimum costs per curriculum reached after a while results from the fact that, at a specific point, the number of course materials that have to be newly created will not decrease anymore. Otherwise, a 'new' curriculum would contain nothing new.

6.3. *Work plan*

This section should present a time frame for the project. This is beyond the scope of the Concept Paper. However, the main milestones for the project have been identified. The work to be performed has been subdivided into 7 work packages, which are represented in the milestone chart. The milestones described in Table 13 represent important and measurable steps in the project.

For the realization of these milestones, the work could be distributed as shown in Table 14.

To provide guidance in developing the Work Plan and Work Packages, the Workshop proposed that the developed system should have the features shown in Table 15 after each of the first three years of development.

The last line in Table 15, cost distribution, indicates that 30% of the total budget would be needed to fund the first year of the effort, 45% of the total budget would be needed to fund the second year of the effort, and 25% for the third year. This reflects the typical 'ramp-up/ramp-down' spending pattern of system implementation projects.

6.4. *Cost estimates*

For estimating the overall costs for the whole project, a detailed business plan has to be developed. Besides the estimates of content preparation, which were 510 man-years for the basic 24-course curriculum (see Section 5.4), and \$6.8 million for the equipment (see Section 5.5), one must also develop an estimate for the system development

Table 14. Project Work Packages

WP1:	Project Management
WP2:	Detailed specification of the courseware structure and software system
WP3:	Setting up the application environment
WP4:	System development
WP5:	Courseware creation
WP6:	1st Evaluation
WP7:	Course delivery (lecturing)
WP8:	Marketing
WP9:	2nd Evaluation

and implementation costs of the Course Delivery System. Based on figures from a variety of ITBT and Tele-Teaching Projects in which the Institutes of the International Network of Computer Graphics has participated in the past 6 years, we estimate that \$30–\$50 million will be required.

More specifically, Table 16 shows the estimated expenditures on system design and development by project.

All these projects were pilot implementations. Therefore, they did not have to meet the robustness standards of an operational system. Furthermore, they did not have to provide the administrative services and security expected of a fully operating system. In addition, these systems were built to support anywhere from 100 to 500 students and built to deliver 3–10 ITBT courses simultaneously. While the system development costs certainly do not scale linearly with the number of students and the number of courses, nevertheless, there are increased costs with a greater number of students and courses. These development costs are partially due simply to managing and coordinating an implementation effort with the scale and complexity of the larger operation.

These four pilot projects, taken together, are somewhat similar to the total system design and development cost that might be expected for the Malaysian implementation if it were done on a pilot basis. However, given the needs of an operational system, we can multiply by a factor of 5 to 10 to account for the scale and complexity of the project and for the need for robustness, administration, and security. This yields the estimate of \$30–\$50 million as stated above.

Better estimates should be developed during a pre-proposal design stage following the Workshop, where a detailed work breakdown structure should be proposed and detailed manpower estimates are made for each element of work. Then the tasks have to be assigned to labor categories of workers (e.g., system designer, C programmer, technical writer) and allocated to project team members (e.g., Fraunhofer, commercial software developers, local university and local commercial software developers). Finally, using known person-year rates for each labor category for each partner, one could use a spreadsheet to calculate and show the expected total costs of the project.

Table 15. System features by year of implementation

System Feature	After Year 1	After Year 2	After Year 3
Network	LAN	MAN and ISDN	all, including ATM
Authoring software	commercial off the shelf (COTS) plus software from Darmstadt	enhanced software based on software from Darmstadt	COTS plus enhanced software
Delivery server	online	hybrid	all
Client	asynchronous and synchronous communication	simple Computer Supported Collaborative Work (CSCW)	more complex CSCW
Infrastructure including Authoring places, learner places, course server, lecture room, MM server	10% of Table 9	50% of Table 9	100% of Table 9
Administration	courseware, user profiles	student records, accounting and billing	full life cycle courseware management in place
Security	copyright protection	user authentication	full security
Learning scenario	individual learning and classroom lecturing plus tutoring	simple group learning	complex group learning
Test population	university students	industrial (e.g., KKIP companies)	region (e.g., MSC) and world continuing education of individuals
Course elements	all object types	system adapts to the client and the network situation	system adapts to the client and the network situation
Examination Process	traditional evaluation methods	protocols and results available to evaluator	more system tools to assist with evaluation
Local environment and set-up	to be specified by the local stakeholders	to be specified by the local stakeholders	to be specified by the local stakeholders
Cost distribution	30%	45%	25%

6.5. *Income estimates*

It is beyond the scope of this Concept Paper to make a full income analysis. This will require input from local government and industry as well as a market analysis of the prospects for selling continuing education over the Internet. Nevertheless, the following factors have to be taken into account when estimating income:

- There are three main sources of income:
  1. From government stipends for students attending the University.
  2. From company employees getting training via ITBT methods (typically paid by the company).
  3. From individuals seeking advanced training or continuing education; these individuals might be located in Malaysia (e.g., working for companies in the Multimedia Super Corridor), in the SE Asia region, or anywhere in the world.
- The courses delivered to the companies might have different fees (less) and might have to be negotiated.
- At the beginning, the courses delivered to the world might have to be offered on a relatively low cost basis in order to achieve a wide penetration of the market.

6.6. *Risk analysis and conclusion*

While it is beyond the scope of this Concept Paper to prepare a full risk analysis, it is clear that pilot implementations of critical elements of the systems architecture and learning scenarios (such as those proposed at the end of Section 4 and a preceding section of this part) would serve to reduce the technical risk. These pilot implementations should proceed in parallel with the two other key elements: (i) the development of a Case Study curriculum (as proposed in Section 5) and (ii) the writing of a full Business Plan from a local as well as global perspective, including a market analysis of the competition for the 3rd phase of deployment—reaching the Internet/WWW consumer.

7. GLOSSARY

Administrator	Any person who is in charge of and administers a learning resources facility like a *Local Training Center*.
Asynchronous communication	Any communication process where sending and receiving do not happen simultaneously, but where there is a considerable time delay (e.g., e-mail, video-on-demand) between emission, reception and consumption.

Asynchronous learning Any learning process where the learner reviews/receives the learning material at a later time than the material was created (e.g., pre-recorded lectures).

Author A person that conceives and develops courseware.

BBB Acronym for 'Basic Building Block'. A self contained courseware unit (module) of short to medium length that leads the learner from an introduction of a subject to its presentation, exploration, and evaluation and that, by being modular (see *Modularity*), can be re-used in several different contexts.

CBL Acronym for 'Computer Based Learning'.

CC Acronym for 'Common Criteria'. Harmonizes criteria used in the U.S. and in Europe to evaluate security products.

COBRA/STI Acronym for 'Cooperation within Bureau, Research and Administration', a project sponsored by German Telekom AG and the Fraunhofer Society (see Appendix C: COBRA STI).

CBT Acronym for 'Computer Based Training'.

CGI Acronym for 'Common Gateway Interface', a standard for programs that extend the capabilities of World Wide Web servers to communicate with other applications.

Compound Object A multimedia object assembled from several objects of the same or different types that, together, make up a coherent object and have some kind of interdependency (e.g., sequencing).

CPS Acronym for 'Characters Per Second'.

Courseware IT-based learning materials that have been assembled so that they, together, make up complete courses or even complete curricula.

CTA Acronym for 'Common Training Architecture', a project sponsored by the DELTA program (see Appendix C: CTA).

DEDICATED Acronym for 'Development of a new Dimension in European Computer-Aided Teaching and Education'. It represents two projects, one sponsored by the DELTA program and one by the COMETT program (see Appendix C: DEDICATED (DELTA) and DEDICATED (COMETT)).

DELTA Acronym for 'Telematics for Flexible and Distance Learning', a former research and technology development program of the STIG (General Purpose Telematics Systems) Program integrated in the European Union's 3rd Framework Program, which lasted from 1991 to 1995.

Direct Reference (*DR*) Reference to learning material that uniquely identifies the material in the learning domain.

DL Acronym for 'Distance Learning', a learning scenario in which learners are away from any teaching institution and learn by using learning materials distributed by conventional means (e.g., post) or through advanced telecommunication facilities.

DR See *Direct Reference*.

Ethernet A network type used for LANs (see *LAN*). Today, the most common transfer rate used with Ethernet is 10 Mbit/sec. Because of the data transfer scheme, the actual network load should not exceed 10–15% of the maximum bandwidth.

EURO-ISDN A complete specification for ISDN systems (see *ISDN*). The ISDN standard is used in Malaysia and the European Union. It offers a base rate of 64 Kbit/sec for data transmission (using the X.75 protocol for data transfer). EURO-ISDN is not used in the U.S., where 56 Kbit/sec base rates are used (as defined in the V.120 protocol).

GA Acronym for 'Graphical Authoring', an authoring environment fully supported by a graphical interface.

Group Learning Learning process by which several learners carry out the study of the same subject conferring with notes and ideas and intensively interacting during study periods.

H.261 ITU Standard for video codecs; a video-compression algorithm designed specifically for video-conferencing.

H.32x A series of ITU standards for video-conferencing. Currently, H.320, H.323, and H.324 have been defined. They differ in the network types used to provide video-conferencing services. The H.320 standards cover audio, video, and call-control procedures. It is based on the H.261 standard for codecs.

H.320	ITU standard for video-conferencing over ISDN. Video-conferencing systems from different vendors conforming to H.320 can be interconnected.
H.323	ITU standard for video-conferencing over TCP/IP. Video-conferencing systems from different vendors conforming to H.323 can be interconnected.
H.324	ITU standard for video-conferencing over POTS. Video-conferencing systems from different vendors conforming to H.324 can be interconnected.
HTML	Acronym for 'Hypertext Markup Language'.
IDEALS	Acronym for 'Integration of Dedicated For Advanced Training Linked To Small And Medium Enterprises and Institutes Of Higher Education', a project sponsored by the Telematics Application Program (see Appendix C: IDEALS).
Interoperability	The ability of two or more given systems (devices, databases, networks, or technologies) to interact with one another in accordance with a prescribed method.
IPR	Acronym for 'Intellectual Property Rights', e.g., the rights of an author for a book or for courseware.
ISDN	Acronym for 'Integrated Services Digital Network'. A standard for digital data transmission.
IT	Acronym for 'Information Technology'.
ITBT	Acronym for 'IT-Based Teaching and Training'. This includes support for a much richer set of learning scenarios than traditional *CBT*.
ITSEC	Acronym for 'Information Technology Security Evaluation Criteria'. A set of criteria for the evaluation of security products defined by European Countries.
LAN	Acronym for 'Local Area Network', a network of computers that are geographically very close (e.g., in the same building or in adjacent buildings) and which is usually based on very fast communication facilities.
Learning Scenario	A concrete situation in which one or more learners engage in learning activities (e.g., a student in the classroom, group learning) and the environment where this situation happens.

Lecturing	Teaching process by which a teacher presents and discusses a theme to learners either synchronously (in the same place or remotely) or asynchronously mediated by some recording media (e.g., videotape). Attendees need not gather in the same place to attend lectures but can attend them from different remote locations.
Local Training Center	A site that combines the expertise of one or more knowledge or research subjects, teaching expertise, and IT resources from which learners can obtain and follow courseware.
LTC	See *Local Training Center*.
Mapping	Process by which a virtual reference is resolved into one or more *Direct References*. The objective is either to find the direct references that fall within a given range or the direct reference that best fits the set criteria. The mapping process may be influenced by *Profiling*.
MBone	Acronym for 'Multicast Backbone'. A virtual network consisting of hosts connected to the Internet and communication using IP-Multicast. MBone provides the functionality for real-time communication like audio- and video-conferencing.
MBone Tools	Software used for real-time communication based on the TCP/IP protocol, especially between hosts belonging to the MBone part of the Internet. *vat* for audio communication and *nv* (network video) are the most common tools.
MCU	Acronym for 'Multi-point Control Unit'. An MCU is software used for audio- and video-conferencing between more than two participants. All communication data is send to the MCU which distributes it to all participants.
Micro-Worlds	Simulations used for exploratory learning. A set of objects and their behavior is modeled. Trainees can interact with the objects and learn about the interconnection of parameters defining object behavior. Micro-Worlds modeling objects that are normally found in research laboratories are often called *Virtual Laboratories*.

Mirroring — A technique used to improve performance on wide area networks whereby copies of important parts of an online resource (e.g., a database or course content) are placed on multiple servers.

MMDB — Acronym for 'Multimedia Database'.

Modularity — A property of one or more assembled objects that, together, carry out some content and that, because they are self-contained, may be re-used in several different contexts.

ODL — Acronym for 'Open Distance Learning' (see *DL* and *OL*).

Off-line Learning — Any learning process in which there is no network transport of learning material at learning time and in which the learner obtains the learning materials from his or her local workplace (e.g., personal computer). Note that such local material might have been distributed via a CD-ROM that is locally mounted or might have been previously batch downloaded from a server.

OL — Acronym for 'Open Learning', a learning scenario where learners follow courses of their choice without following a predefined curriculum.

Online Learning — Any learning action that is mediated by the network, e.g., a learner located at, say, home who simultaneously requests, receives, and consumes learning material from a remotely located material server.

POTS — Acronym for 'Plain Old Telephone Service'. Refers to conventional telephone connections used for analog data transfer.

Profiling — All actions leading to the recording of user actions and learning performance that (dynamically) characterize the user.

Scenario — See *Learning Scenario.*

Standalone Learning — A learning process by which a learner acquires knowledge by studying alone (sometimes confused with *off-line learning*).

Synchronous communication — Any communication process in which sending and receiving happen simultaneously and in which there can be a two-way interaction between both ends (e.g., video conferencing).

Synchronous learning	Any learning process in which learners watch the lecture in real time (although not necessarily at the place where the lecture is taking place) or interact among themselves using synchronous communication facilities.
TCP/IP	Acronym for 'Transfer Control Protocol/ Internet Protocol'. The standard network protocol for packaged data transfer on the Internet. It can be used with different basic types of networks such as *ISDN* or *Ethernet.*
Telematics	The application of information and communications technologies and services, usually in direct combination.
Telematics Infrastructure	The assemblage of telecommunications and information-processing systems and services that offer a base for telematics applications.
Teleservice	A service provided from a remote location using the telematics infrastructure.
Telework	Work carried out using the telematics infrastructure at a place other than that where the results of the work are needed. This definition covers home, mobile, or 'elecottage'-based teleworkers employed by an organization; independent workers; and teleservice companies offering specific services to both firms and individuals.
Trainee	Any person who follows a course to learn a specific skill for practical purposes.
Tutor	See *Tutoring*.
Tutoring	Teaching process by which learners are led and counseled by a teacher in real time (or through some asynchronous communication means) and, thus, receive intensive personal assistance.
TTT	Acronym for 'Tele-Teaching and Training', a project sponsored by the German Federal Government (BMBF) with the backing of the DFN Association (see Appendix C: TTT).
User Profile	See *Profiling*.
V.34 / V34+	A network protocol used for analog data transfer. V.34 allows for a maximum transfer rate of 28 800 bits/sec (bps), V.34+ for 33 600 bps.

V.56 A network protocol used for connections from analog modems to *ISDN* modems. It allows for a maximum transfer rate of 56 000 bits/sec (bps). V.56 is not suitable for connecting analog modems to each other. It will usually be used for dial-up connections to an online service providing ISDN-access with 56 000 bps.

Virtual Reference (*VR*) A reference to learning material that specifies which characteristics and attributes (e.g., context, keywords, language) the target learning material must have. A Virtual Reference may be resolved into several *Direct References* (also see *Mapping*).

VirtualX A cooperative multimedia environment supporting application sharing of X-Windows applications.

VR See *Virtual Reference*.

VTC Acronym for 'Virtual Training Center'. The expression refers to a group of interconnected server sites that present themselves as a united entity to their customers.

WAN Acronym for 'Wide Area Network', a network of computers that are widely dispersed, even world-wide.

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APPENDIX A

At the Workshop held in Sabah on March 11–13, 1997, the following leading international experts (Type II Experts) participated and also provided significant input for this Concept and System Architecture Paper:

Name	Institute	City/Country
J. Brisson-Lopes	Instituto Superior Técnico	Lisbon/Portugal
J. Encarnação	Technische Hochschule Darmstadt	Darmstadt/Germany
M. Gross	Technische Hochschule Zürich	Zürich/Switzerland
O. Spaniol	RWTH Aachen	Aachen/Germany
J. Teixeira	University of Coimbra	Coimbra/Portugal
A. van Dam	Brown University	Providence/USA
M. Wilson	Rutherford Appleton Laboratory	Chilton/UK
M. Zyda	Naval Postgraduate School	Monterey/USA

Also at the 'IT-Based Lifelong Learning Systems' Workshop in Sabah on March 11–13, 1997, the following local and regional experts (Type III Experts) participated, and many of their contributions and insights are rep-

resented in the final draft of this Concept Paper:

Name	Institute	City/Country
YB Datuk Tham Nyip Shen	Deputy Chief Minister cum Minister of Industrial Development	Kota Kinabalu, Sabah, Malaysia
Tan Sri Osman Yeep Abdullah	Chairman, Multimedia Development Corporation	Kuala Lumpur/ Malaysia
Prof. Dato' Dr. Abu Hassan Othman	Vice Chancellor, Universiti Malaysia Sabah	Kota Kinabalu, Sabah, Malaysia
Mohd. Noor Moktar	Permanent Secretary, Ministry of Industrial Development	Kota Kinabalu, Sabah, Malaysia
Tsen Kui On	Principal, Sabah Tshung Tsin Secondary School	Kota Kinabalu, Sabah, Malaysia
Awang Kamaludin Jumat	Telekom Malaysia	Federal Territory, Labuan, Malaysia
Zulfikar Ahmad	CELCOM (Cellular Communications Network) Malaysia	Kota Kinabalu, Sabah, Malaysia
Loi Lung Kiong	Managing Director, MGR Corporation Berhad	Kota Kinabalu, Sabah, Malaysia
Prof. Madya Dr. Ithnin Bujang	Universiti Malaysia Sabah	Kota Kinabalu, Sabah, Malaysia
En. Sofien Azmi bin Tejul Arus	Education Department	Kuala Lumpur, Malaysia
Prof. Han Dr. Chun Kwong	Universiti Pertanian Malaysia	Serdang, Selangor D. E., Malaysia
Edwin Liew	Director, K.K.I.P. Communications Sdn. Bhd.	Kota Kinabalu, Sabah, Malaysia
Dr. Mohd. Yaakub HJ. Johari	IDS	Kota Kinabalu, Sabah, Malaysia
Dr. Chin Wei Ngan	Senior Lecturer, NUS	Singapore
Dr. Tommi Chen	Asiapac	Selangor, D.E., Malaysia
Dr. Pang Teck Wai	Associate Director, IDS	Kota Kinabalu, Sabah, Malaysia
Dr. Bilson Kurus	IDS	Kota Kinabalu, Sabah, Malaysia
Chong vun Then	IDS	Kota Kinabalu, Sabah, Malaysia
Bruno Vun	IDS	Kota Kinabalu, Sabah, Malaysia
Helen Liew	K.K.I.P. Communications Sdn. Bhd.	Kota Kinabalu, Sabah, Malaysia
Chung Chin Hing	K.K.I.P. Communications Sdn. Bhd.	Kota Kinabalu, Sabah, Malaysia

APPENDIX B: *Recommendations*

B.1. Full Specification

Develop a full specification of the system architecture; support this by early prototyping.

B.2. Critical Paths And Key Concepts

Use the early prototypes to test critical paths and key concepts (e.g., by using test cases already partially developed in the IDEALS and COBRA projects).

B.3. Training Of Local Implementers

Use the early prototypes to train the local implementers in the concepts and system architecture.

B.4. Case Study Content

Form a team of international experts for the further detailing and development of the content for the case study. Herein, the following tasks should be accomplished:

specify individual course lengths and content,
identify laboratory components,
clarify the role of the thesis,
allocate resources to individual courses,
define a subset of courses for testing the system,
identify a subset of courses with industrial relevance,
identify, propose, and assign courseware providers for the specified courses.

B.5. Privacy And Security

Use the early prototypes to test and validate the privacy, security, and authentication mechanisms chosen for the delivery and administration system.

B.6. Evaluation

During the prototyping stage, integrate independent evaluation mechanisms for continuous quality feedback into the work plan (as described in Section 5.6).

B.7. Business Plan

Develop a full, detailed business plan, including a risk analysis. Use the early prototypes to validate the risk analysis.

APPENDIX C: *Project References*

C.1. DEDICATED (DELTA)—Development Of A New Dimension In European Computer-Aided Teaching And Education

Project sponsor/client: Telematics for Flexible and Distance Learning (DELTA) Programme of the EU.

Overall Project Costs:	Project funding:	Person months:
3 805 000 ECU	1 932 000 ECU	381.7
Start:	End:	Duration in months:

1 January 1992	31 December 1994	36

C.1.1. Objectives Of The Project

DEDICATED's aims were to:

Deploy and pilot test a European-wide network of Local Training Centers, which cooperated in the development of common curricula and platform-neutral reusable courseware to train users in Computer Aided Design and Computer Aided Manufacturing.

Develop and demonstrate a new concept of a multimedia, multipurpose Modular Training System supporting the most common hardware/software platforms (Windows PCs and UNIX workstations), thus providing interoperability between heterogeneous Local Training Center platforms by means of portable tools to facilitate local and remote access to modular multimedia courses to learners, tutors and teachers.

The rationale behind DEDICATED aimed at satisfying user needs that were being felt during the early 1990s when users became unsatisfied with the existing monolithic CBT systems and the emergence of new learning scenarios that called for continual lifelong learning on demand. The stress on the word 'modular' was the response to the need for the reduction of multimedia courseware cost by enlarging the target population and reuse of courseware fragments already available.

The project developed a learning structure, learning scenarios and course libraries to give learners access to training materials and establish Local Training Centers as centers of local teaching expertise which were interconnected to form a European-wide network of computer-based training sites. These centers supported courseware designers and developers, learners and teachers, administrators and managers. These concepts supported and demonstrated several different learning scenarios as standalone learning, distance learning and interactive teaching.

DEDICATED successfully demonstrated its concept of a cross-platform CBT system and of the modular courseware concept, which made courseware independent of the hardware and software platforms. These advantages overcame the drawbacks of the monolithic CBT systems of the time. Above all, the modular courseware concept enabled the intensive reuse of courseware modules from one course in other courses, bringing along the obvious decrease of courseware development cost.

It is well worth mentioning that DEDICATED achieved these results while delivering high quality, multimedia courses which were contributed by the Local Training Centers' partners before the advent of the WWW at a time when the network infrastructure lacked the bandwidth that is available today.

DEDICATED proved to be one of the most successful projects of the DELTA Programme. This success triggered its natural continuation through the IDEALS project (Integration of DEDICATED for Education and Training in Small and Medium Enterprises and Institutes of Higher Education), sponsored by the 4th Framework Program of the European Union.

C.1.2 Major Results

- Local Training Centers were established in Portugal, France, Germany and Greece in order to test the philosophy and implement the DEDICATED MTS.
- The feasibility of the system to operate across local area networks on both MS-Windows and UNIX platforms was successfully demonstrated.
- The Modular Training System software which consists of a number of different layers. The Generic Learning Support layer provides the generic user interface. The device-independent Learning Material Layer facilitates course development while the technology-independent Course Material Layer supports course delivery dependent on specific learning goals.

C.2. DEDICATED (COMETT)

COMETT/DEDICATED B Development of a new Dimension in Computer Aided Teaching and Education

Project sponsor/client: COMETT Programme of the European Commission

Overall Project Costs:	Project funding:	Person-months:
900 000 ECU	375 000 ECU	168
Start:	End:	Duration in months:
1 July 1992	30 June 1995	36

C.2.1. Objectives Of The Project

The main objective of COMETT/DEDICATED (Development of a new Dimension in Computer Aided Teaching and Education) was the development of a set of training courses at the post-secondary level and their installation and trial on an European-wide infrastructure of so called Local Training Centers (LTCs) as local centers of training excellence. This environment provided optimal synergy and the mutual influence that is necessary to develop a long-term strategy for European-wide Computer-Based Training.

The expertise of the research and teaching staffs of the various Institutions and Companies cooperating on the project has been put together in order to:

1. Develop multimedia training material.
2. Test the developed material in real environments, through seminars and short courses.
3. Evaluate the delivery of courses in Local Training Centers (LTCs).
4. Promote the exchange of training material through a European Network of LTCs.

The concept of LTCs allows the introduction of Advanced Learning Technology, in training, in Advanced Manufacturing Technologies and multiple Computer Graphics Applications on an European Community-wide-basis. These objectives have been met by establishing four pilot installations for training and training material delivery in four European countries: Portugal, Germany, France, and Greece. An LTC serves as a common platform to support the different user groups involved in the process of learning and teaching: the designers and developers of courseware, the teachers/trainers and the learners.

Based on the general concept of an LTC, COMETT/DEDICATED aimed at prototyping and testing courses and covered the aspects of training applications, ensuring that the expected results are close to the market. The development of different types of training materials is regarded as of great interest in sustaining basic and continuing education in industrial sectors that intensively apply Advanced Manufacturing Technologies, with a special emphasis on Mechanical CAD/CAM/CAE and Computer Graphics Applications, but where qualified personnel is still scarce. It was assumed that specialized training in the various technologies encompassed by the titles, Advanced Manufacturing Technologies and Computer Graphics

Applications, required different approaches, both pedagogical and technological, and the contribution of multidisciplinary teams. Furthermore, the experience garnered through course development by several experts sharing different viewpoints, experiences and backgrounds, promoted the development of a suitable framework, enabling the extrapolation of the pilot courses to other environments.

COMETT/DEDICATED was demonstrated and evaluated in pilots for Institutes of Higher Education and Small and Medium Enterprises (SMEs).

C.2.2. Major Results

The results of the COMETT/DEDICATED Project were the following courseware courses:

- Geometric Modelling for Design and Manufacture: introduction to geometric modelling, representation schemes, free-form modelling, and product modelling.
- Computer Graphics Programming: introduction to Computer Graphics Systems, GKS and PHIGS.
- Computer Aided Manufacturing for SMEs: introduction to manufacturing technologies and flexible manufacturing systems.
- Basics of 3D Computer Graphics and Animation: introduction to 3D computer graphics and animation, computer graphics design, animation systems and development of animations.
- 3D Animation software (TDI-EXP) basic training: system-specific training course.

C.3. CTA—Common Training Architecture

Project sponsor/client: DELTA Programme of the European Commission.

Overall Project Costs:	Project funding:	Person-months:
3 000 000 DM	2 000 000 DM	120
Start:	End:	Duration in months:
1 July 1994	30 June 1997	36

C.3.1. Objectives Of The Project

Common Training Architecture (CTA) has been carried out by a European consortium. The consortium consisted of training providers, enterprises, and research institutions including the Fraunhofer-Institute for Computer Graphics.

The objectives of CTA are the development of a common training architecture directed at the harmonization of technologies, systems and infrastructures, and their adaptation to flexible international distance training services. These objectives imply also a long-term view of the requirements of key players. Unlike other architectures that try to define a single solution, CTA is a framework and process and is based on the principle that diversity and change are forces to be harnessed rather than resisted. The CTA enables an education and training enterprise to develop its own unique architecture as the means to implement information systems that actually meet business needs.

C.3.2. Major Results

CTA is explained in a series of volumes, each one concentrating on one aspect in particular. Each volume provides a study of the major technology trends and offers detailed advice and guidance for decision making.

The compete series is published in: CTA Handbook series/ed. W.A: Verreck *et al.* Heerlen: CTA Consortium. ISBN 90-358-1380-4.

The following are the most important volumes

- Open Communications Interface (OCI)/authors H. Creff and J. Fromont; editors W.A. Verreck and H.G. Weges, ISBN 90-358-1372-3
- Common Information Space (CIS)/authors M. Capurso and M. Malerba; editors W.A. Verreck and H.G. Weges, ISBN 90-358-1374-X
- Learning and Training Common Information Space Reference Model/authors CTA Consortium, DELTA project D2023 deliverable 12.

C.4. COBRA STI—cooperation Within Bureau, Research And Administration

Project sponsor/client: German Telekom AG, Fraunhofer Society

Overall Project Costs:	Project funding:	Person-months:
3 000 000 DM	2 000 000 DM	120
Start:	End:	Duration in months:
1 July 1994	30 June 1997	36

C.4.1. Objectives Of The Project

COBRA-3 is a project for developing and evaluating telecommunication-based applications. Eleven Fraunhofer-Institutes participate in the project initialized and coordinated by the Fraunhofer-Institute for Computer Graphics. They use state-of-the-art telecommunication technologies to provide advanced services for facilitating multimedia and computer-mediated-cooperation.

COBRA-3 consists of six application scenarios, one of which is COBRA STI (*Teaching, Training and Information*). In this scenario, a system for distributed training is developed and used with four courses on ASIC-design, CAD-software, logistics, and quality management. Thus, Internet-based Training is evaluated with several small and medium enterprises.

In COBRA STI, cooperation between Fraunhofer-Institutes and enterprise partners for course creation and delivery is established. During the project, Fraunhofer-Institutes provide system software, courseware, and support. Enterprises use the courses for internal training and evaluate the system. Several companies are expected to develop their own courses for the COBRA STI platform after the project.

C.4.2. Major Results

In COBRA STI, a system platform for Internet-based training is developed as well as courses to be delivered by this platform.

The 'COBRA STI system platform' is based on Internet standards. A standard WWW browser, extended by Java Course Control software, is used as client. Any state-of-the-art WWW server can be used to connect trainees to the COBRA-STI-Training-Server that manages continuous training sessions and adapts course flow to specific user profiles.

The didactic approach is based on goal-oriented learning. Content is contained in so-called presentation items and clearly separated from the course structures defined in knowledge items and learning goals. Dependencies among knowledge items are described by a graph, whereas learn-

ing goals form a hierarchy on top of the knowledge domain.

The COBRA–STI-Courses cover the following topics:

- ASIC-Design with Xilinx
- Introduction to CAD
- Simulation for Logistics
- ISO 9000 Quality Management

C.5. TTT—Tele-Teaching And -Training

Project sponsor: German Federal Government (BMBF) with the backing of the DFN Association

Overall Project Costs:	Project funding:	Person-months:
2 811 000 DM	1 967 600 DM	76
Start:	End:	Duration in months:
1 February 1995	31 December 1996	23

C.5.1. Objectives Of The Project

The objectives of the project, Tele-teaching and -training (TTT), are to make progressive multimedia techniques and high-speed networks available for instructional and training purposes. Several concrete instructional programs were implemented and examined on the basis of their efficiency and acceptance by instructors and students alike. The aim of the project is to obtain concrete results regarding system design and performance in order to offer tele-teaching, in its full diversity, along a wide economic front.

The two major goals are to support:

- remote participation during on-line lectures
- time-shifted participation in lectures.

These scenarios allow for place- or time-independent study and were developed as a consequence of the local situation in Darmstadt. The campus of the Technical University is divided into different locations: there are university buildings in the center of town and outside of town. The lecture rooms are connected via an high-speed ATM network. Two lecture roomsCone in each campus partCwere equipped with new media and techniques. Each lecture room has a multimedia workstation, a data projection system, one to three video cameras, and audio equipment.

The TTT project includes the following lectures:

- Database Systems I (computer science department)
- Computer Graphics I (computer science department)
- Software Engineering (computer science department)
- VLSI System Design (computer science department)
- Product Data Technology (mechanical engineering department)
- 3D-CAD Practical Training (mechanical engineering department).

Several lectures were recorded with a digital video camera. The raw material was prepared using the AVID Media Suite Pro video/audio editing software and, afterwards, stored in the Multimedia Database (MMDB). The MMDB is based on a commercial, object-oriented database management system which was enhanced by the Fraunhofer Institute for Computer Graphics to store and retrieve monomedia and multimedia objects hierarchically. The retrieval mechanism is supported by keyword and free text search. A WWW server on top of the MMDB prepares the data and Netscape Navigator is used to present it.

Students may access the learning material for self-directed completion of exercises and practical training or for examination preparation. They get the advantage of free time scheduling as well as the ability to repeat sections on demand. This time-shifted participation in lectures is supported by further digital learning material (e.g., lecture notes and slides) which are also stored in the MMDB. To present the video and audio sequences, the system, AVWOD (Audio, Video and Web-On-Demand), is used. The three media (video, audio and HTML-slides) are synchronized and presented with the MBone tools, *vic* and *vat*, and a WWW viewer.

C.5.2. Major Results

The results of the TTT project are the following:

- a first prototype for tele-teaching and tele-training
- digital multimedia learning material: lecture notes (more than 1500 HTML pages including over 4000 figures), slides, more than 20 h of video sequences, 30 video clips (instructional films, about 35 min each), animation sequences, and more than 145 audio files)
- experience concerning the set-up of the technical equipment and infrastructure, authoring, storing and presenting digital multimedia learning material, realization of the TTT-based lectures, the students' acceptance of new learning media as well as the instructors' reception for innovation in education.

C.6. IDEALS—Integration Of Dedicated For Advanced Training Linked To Small And Medium Enterprises And Institutes Of Higher Education

Project sponsor/client: Telematics Application Programme of the European Commission

Overall Project Costs:	Project funding:	Person-months:
3 402 159 ECU	1 800 000 ECU	352.5
Start:	End:	Duration in months:
1 January 1996	31 June 1998	30

C.6.1. Objectives Of The Project

The IDEALS project aims at installing and positioning flexible, on-demand, telematics-based distance learning and training services in the market. A Modular Training System (IDEALS-MTS) will be developed, and a European-wide network of Local Training Centers (LTCs) will be established. The Modular Training System will allow cost-effective co-authoring of courses and flexible, cost-effective learning for users. The IDEALS project will enhance the results of the DEDICATED project (3rd Framework Programme) and transform them into marketable products.

In IDEALS, the Modular Training System will be enhanced to support multiple users at the same time. Courseware, stored in a distributed database, can be enriched by using real-time simulations (micro-worlds). Support will be provided for course authoring, learning, and tutoring.

The Local Training Centers are interconnected to provide a uniform courseware domain with European-wide access. Different forms of networking will be tested like modems, ISDN, Internet, and satellite links.

IDEALS will be demonstrated and evaluated in pilots for Institutes of Higher Education and Small and Medium Enterprises (SMEs). In the Institutes of Higher Education

Pilot, Technische Hochschule Darmstadt (Germany), University of Oulu (Finland), and Universidade de Coimbra (Portugal) will jointly create courseware on the topic, 'Fundamentals of Computer Graphics', by using tools for cooperative authoring and on-line communication. These institutes are connected via terrestrial links and satellite. The resulting courseware will be used later in their lecturing activities. Students (about 200 in total) can access this courseware in computer labs at their university (electronic classroom) as well as at home (home learning). Remote tutoring and group learning will be supported.

In the SME Pilot, seven courseware providers will jointly create courseware on the topics, 'Parametric Design', 'Telematics Usage', and 'Quality Management'. Customized versions of these courses are delivered to approximately 20SMEs. The SMEs in rural areas in Portugal are connected to the LTC via satellite modems. The trainees (about 150 in total) can access the courseware either from their working place or in training labs of SMEs, specialized in providing training to external customers. The SMEs involved in this pilot are located in Germany, Greece, Portugal, and the Netherlands.

As a result, IDEALS will deliver a client/server-based learning and training system, consisting of a client application—running at the learner's workplace, powerful servers—running at the LTCs, and a distributed database. A European-wide courseware domain will be created, and courses based on this domain will be offered on a commercial basis. Tutors located at the LTCs will provide interactive, on-line help for local and remote learners.

C.6.2. Major Results

The results of the IDEALS Project will be the following:

- The *software package* developed within the IDEALS project (the Modular Training System MTS) consists of two major components:
- the MTS-Client, encapsulating all functionalities of the end user's workplace (Trainees as well as Authors)
- the MTS-Server, together with the MTS-database, encapsulating the functionalities necessary to provide the courseware material and to execute courses.

The *courseware domain* and the *customized courses* generated and adapted within IDEALS drawn from the following areas:

- Fundamentals of Computer Graphics
- Parametric Design
- Telematics Usage
- Quality Management.

APPENDIX D: *Open Issues*

D.1. Certification

To what extent will the Case Study address the question of CertificationCfor the university student, for the industrial trainee, for the Internet-based continuing education student?

D.2. Course Delivery

To what extent will the fact that we want to offer the same courses to three different target audiences affect content and curriculum development? In particular,

- Are the same courses to be delivered to the three locations (university, industrial park, the world over the Internet)?
- Is the academic credit system the same?
- Is the billing scheme the same? Will the answer to this question affect the business plan?
- Is the delivery system for supporting traditional learning at the university different from the delivery system used for supporting training at the industrial parks?
- To what extent can individual course modules of the case study be reused for different target audiences?

D.3. Courseware Design

- Is there a need for formal methods to support computer-aided courseware engineering (CACE)?
- To what extent can we carry over existing methods from software engineering?